OBITUARY NOTICES

OF

FELLOWS DECEASED.

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PIERRE EUGÈNE MARCELLIN BERTHELOT, 1827—1907.

MARCELLIN BERTHELOT was a native of Paris, born on October 25, 1827, in a flat looking on to the Rue du Mouton, situated in the Place de Grève, now owing to the activity of Baron Haussmann, the Place de l'Hôtel-de-Ville. His father, a doctor of medicine, was a member of the sect of the Jansenists, a small branch of the Gallic Catholic Church. He was a serious man, impatient with the folly of his "concitoyens," and somewhat depressed by the poverty and sufferings of his patients. The "Church of Faith" had its own Liturgy, and the congregation joined in singing psalms and hymns. Many of the "prêtres" were among Dr. Berthelot's patients, and young Berthelot must often have listened to discussions on the attempts, ultimately successful, to substitute the Roman for the Gallic liturgy. Dr. Berthelot was married in 1826, shortly after starting practice. His wife was a lively, bright woman, who transmitted her features to her son.

At that time, Charles the Tenth was on the throne. The allied powers had involved France in a "Gouvernement de Curés"; and it was part of the State Ceremonial to form a procession, which was headed by the Holy Sacrament and the Papal Nuncio, a cardinal in red, from the Tuileries to Notre Dame and back, and in which the King, the Queen, the Dauphin (who, according to Madame Berthelot *mère*, was able to look behind him without turning his head), and the Court took part. The spectators, under the penalty of sacrilege, were obliged to kneel as the Corpus Christi procession passed. Those who refused were prosecuted and severely punished.

Such a travesty of religion was not to Dr. Berthelot's taste; the "bourgeoisie" was liberal and imbued with the sentiments of Voltaire; and the Berthelot family was of the bourgeois class. During the revolutions of 1830 and 1848, their house commanded a full view of one of the chief scenes of operation, and young Berthelot must have often been a spectator of many a scene of disturbance and violence. Highly developed intellectually, and mentally impressionable, his later convictions were doubtless largely owing to his early surroundings.

That Marcellin resembled his mother in features has already been mentioned. But the resemblance was not merely external; there existed between them the most intimate sympathy. Their favourite promenade was in the Bishop's garden behind Notre Dame, along the Quays with their stalls of flowers, and in the Jardin des Plantes. Their minds were both quick and versatile; they were eagerly interested in all that passed around them, and, as Madame Berthelot used to say (borrowing the simile from one of the invasions which she witnessed), they could both "drive a Russian team with a sure hand and at a full gallop." The writer, who knew Berthelot only during his later years—since 1878—never conversed with anyone who possessed such rapidity of thought. Given an idea, with his quick discursive mind he would follow out all possible paths and by-ways, seeing the consequences of this assumption and of that, interposing occasionally a quaint remark, not exactly humorous, but " de plaisanterie." He was a delightful conversationalist, interested and intensely interesting, willing to discuss all possible subjects, and willing, too, to hear all varieties of view, even those contrary to his own opinion.

His persistence, energy of character, and devotion to duty were inherited from his father. Berthelot used to regret that he had not inherited his mother's optimism. He used to say that when a misfortune overtook her, she had what the French call a "crise de larmes," soon over, and followed by her usual optimistic cheerfulness; that a rainbow generally rose through her tears, and that she became gaily resigned to the incurable evil.

After the demolition of the Rue du Mouton, the family moved to Neuilly, then quite in the country. Renan often looked in on Sundays as a guest at their midday meal. In one of his private letters he tells how Berthelot and he became friends. He had just renounced his clerical orders, and was "maître-répétiteur" in a school, where he led a lonely and melancholy existence, depressed by the mental struggles which he had come through, and far from his family and his native Brittany. One day, a pupil about four years younger than himself accosted him; the talk became intimate, and a friendship with Berthelot was soon formed, destined to endure for life. Their intercourse was frequent; begun early, when both were slender youths, never a year, hardly a month, passed without their seeing each other. Renan used sometimes to poke fun at Berthelot; the tale is told that, passing a cemetery, Renan said to him: "Là, voici la seule place que tu n'as jamais convoité." Such sallies were always received with amusement and good temper. On another occasion, provoked by the remark that his coat was worn with the air of a cassock, Renan retorted: "What is there in you, Marcellin, that gives you the air of just having left off fighting behind a barricade?" While Berthelot retained his slender form, Renan became very corpulent; Berthelot, nervous and active, maintained to the last his almost feverish love of work; Renan was meditative—almost a dreamer. It was Berthelot's sad duty to speak of his lost friend when the monument at Tréguier was raised to his memory. He emphasised Renan's lucidity even to the end, his power of work, his great mental activity; the words were applicable with equal force to himself.

Never was there a more devoted couple than Monsieur and Madame Berthelot. After he had ended his brilliant career at the Lycée Henri IV, Berthelot gained the prize of honour at the open competition in 1846. Without any coaching, he passed successively all his degrees—Bachelier, Licencié, and Docteur-ès-Sciences; for the doctorate he presented a somewhat sensational thesis, entitled, "The Compounds of Glycerine with Acids, and the Artificial Production of the Natural Fats." While working at this research, he was lecture-assistant ("préparateur") to Balard, at the Collège de France. In 1861, largely through the influence of Duruy, then Minister of Public Instruction, Berthelot was promoted to the Chair of Organic Chemistry in that institution; and there he remained all his life. In that year he was awarded by the Academy of Sciences the Jecker Prize for his remarkable researches on the artificial production of organic compounds by synthesis, and at the same time the Academy recommended the creation of the special Chair which Berthelot filled so long and so illustriously. In his own words: "Adonné, dès mes débuts dans la vie, au culte de la vérité pure, je ne me suis jamais mêlé à la lutte des interêts pratiques qui divisent les hommes. J'ai vécu dans mon laboratoire solitaire, entouré de quelques élèves, mes amis."

When he won the Jecker Prize, he was in his thirty-fifth year. The appointment to the Chair at the Collège de France made it possible for him to marry Mademoiselle Bréguet, the daughter of a French Swiss, whose family had made money by manufacturing watches, famed since the middle of last century. Monsieur Bréguet was a "constructeur industriel," or builder of factories. He lived near the Place de l'Hôtel-de-Ville, on the Quai de l'Horloge, and the families were acquainted from early days. Mademoiselle was a desirable "partie," well dowered, and of great beauty, which she retained up to the end of her life. She was placid in manner, with lovely eyes, and a brilliant complexion, rendered even more striking, when, at an advanced age, her hair was silver; and in the church of Saint-Étienne du Mont, there is a picture of Sainte-Hélène, the lovely face of which is taken from a portrait of Madame Berthelot as a girl. The meeting of the young couple was somewhat romantic; Mademoiselle Bréguet, no doubt, must have appeared to Marcellin to be beyond his reach, and besides, his attention was otherwise occupied. But one day, on the Pont Neuf, Mademoiselle was crossing the longest bridge in Paris in the face of a strong wind, wearing a charming Tuscan hat, then the *mode*. Behind her walked her future husband; suddenly she turned round, to avoid having her hat blown off, and practically ran into his arms. If not exactly love at first sight, it was a case of love at first touch. Their married life was of the happiest; indeed, it may be said that they were in love with each other till the end. One of the sons wrote:—"Mon père et ma mère s'adoraient; jamais le moindre nuage n'avait troublé leur bonheur. Ils s'étaient compris dès le premier jour. Ils étaient si bien faits pour se compléter! Bien que très lettrée et fort intelligente, maman s'était toujours effacée devant son mari, se bornant à s'efforcer de le rendre parfaitement heureux. C'était, à son avis, la seule façon de collaborer à son œuvre." Another intimate friend added:—"Monsieur et Madame Berthelot s'adoraient; tous deux étaient de la nature d'élites; sa compagne n'avait cessé de l'encourager et de le soutenir." No one visiting their house could fail to remark this absolute devotion to each other; never was there a happier family. Although not a conversationalist, Madame Berthelot, by her perfect tact, her serene manner, and her charming sympathetic face, knew how to make each guest appear at his best; the ball of conversation was lightly tossed round the table, Berthelot himself, by his quaint and paradoxical remarks, contributing his share. A dinner at Berthelot's, in his old house in the Palais Mazarin, the home of the Institute, was a thing to be remembered.

Always charitably disposed, Madame Berthelot used to send all the cast-off clothes of the family to the cleaners, and after they had been carefully mended, they were distributed to poor friends.

In 1881, Berthelot was elected a "Permanent Senator"; he thought it incumbent on him to bear his share in the Government of his country. With his wife's help, he managed to carry on his two functions at the same time. In his place in the Senate, Berthelot used to sit buried in his arm-chair, his head thrown back, and his eyes closed, apparently inattentive to all that passed; but nothing of importance escaped him. He took a leading and active part as member of various Committees dealing with education, and in 1886, as Minister of Education in the Goblet Cabinet, he busied himself with the reform of educational methods in such a manner as to acquire a wide popularity; the Bills introduced by him dealt with primary and with higher instruction, with universities, and with technical schools; in the last he was no believer, except in so far as manual training was given. Later, in 1895, he was for a short time Foreign Minister in the Bourgeois Cabinet; but the delays of parliamentary procedure were not to his mind. It was with difficulty that he was persuaded to sign the Anglo-French Treaty defining the position of Siam; and, almost immediately after, he resigned office.

Berthelot's career is easily told; it consisted of honour after honour. He was elected a Member of the Académie de Médicine in 1863, and in 1867 he collaborated in the foundation of the École des Hautes Études, and in the reorganisation of scientific teaching. Membership of the Académie des Sciences followed in 1873, and in 1889 he became its Sécrétaire Perpetuel.

In 1900, he had the rare honour of being elected among the immortal forty in the Académie Française, succeeding to the Chair of Joseph Bertrand. Of 28 voters, 19 voted for him, 9 abstaining. Four years later, in 1904, he delivered the statutory discourse. He was a Member of the *Conseil Supérieur des Beaux-Arts,* of the *Conseil Supérieur de l'Instruction Publique,* and in 1886 he was created a Grand Officier of the Legion of Honour. He was Foreign Member of almost every scientific society in the world, including our own Royal Society.

On November 24, 1901, the Berthelot jubilee celebration, the anniversary of his seventy-fifth birthday, was held in Paris, M. Loubet, President of the Republic, in the Chair. It took place in the great hall of the Sorbonne; all the Cabinet, the Ambassadors of all countries, and delegates from universities and scientific societies from all over the world were present. Madame Berthelot with her children and grand-children occupied a conspicuous place, beaming over with unaffected pleasure; Berthelot had declined the State offer to make a triumphal procession in the carriage of the President with a military escort; he went on foot from the Quai Voltaire to the Sorbonne, his greatcoat buttoned so as to hide the grand-cordon of the Legion of Honour, and his head down so as to avoid recognition. He was embraced by the President of the Republic, and amid the enthusiastic applause of the spectators, address after address was delivered, each delegate conveying the congratulations of the body which he represented. It was a national fête. Thus did the French honour science and its *doyen.*

On March 18, 1907, the end came. Madame Berthelot had been ailing for about three months; it turned out to be an attack of heart-disease, dangerous at the age of seventy. After she was confined to bed, Berthelot watched by her each night, seated in a deep arm-chair, only leaving her when she was asleep. He himself suffered from the same disease, and it was accelerated by his want of rest. His family noticed his feverish appearance in the mornings; he excused himself by saying that he was finishing a memoir for publication. On Passion Sunday there was a slight improvement, and Berthelot passed the afternoon in his laboratory at Meudon. That night, however, Madame Berthelot became comatose, and her husband never left her bed-side until Monday at four, when the end came. Berthelot suddenly rose from the arm-chair in which he was seated, threw his arms in the air, uttered a cry, and fell back dead. They died, as they had lived, together.

It now remains to give a sketch of Berthelot's scientific work. The "Prix-Jecker" has already been alluded to. This was the reward of his labours on the synthesis of carbon compounds. He began in 1851 by investigating the action of a red-heat on alcohol, acetic acid, naphthalene, and benzene; this led him in 1860 to the rediscovery of acetylene, a compound originally obtained by Edmund Davy, Sir Humphry's brother. In 1856, he synthesised methane by the action of a mixture of sulphuretted hydrogen with carbon disulphide on copper; and in 1862 he obtained ethylene and acetylene by heating marsh-gas to redness. His condensation of acetylene to benzene in 1866 established the first link between the fatty and the aromatic series. His direct synthesis of acetylene from carbon and hydrogen in 1862, and the formation of alcohol by hydrolysing ethyl-sulphuric acid, obtained by absorbing ethylene in sulphuric acid, taken in conjunction with his synthesis of hydrocyanic acid in 1868, pointed the way to the formation from the elements of innumerable complicated compounds of carbon.

Much light has also been thrown by Berthelot on the alcohols. In 1857, he produced methyl alcohol from marsh-gas by chlorination and hydrolysis; in 1858, he recognised cholesterine, trehalose, meconine, and camphol as alcohols in 1863, he added thymol, phenol, and cresol to the same class; and he showed how to diagnose alcohols by acetylation.

Turning to the esters, the nature of glycerine occupied his attention in 1853; in that year he succeeded in synthesising some animal fats, and showing their analogy with esters, as has already been mentioned; and he prepared other salts of glyceryl by submitting it to the action of acids. The action of hydriodic acid was, however, found to yield two substances of a different nature, namely, isopropyl iodide, and allyl iodide; and from the latter, he prepared, for the first time, artificial oil of mustard. The analogy of sugars with glycerine led him to investigate the action of acids on sugars, and this resulted in the synthesis of many of their esters. The fermentation of mannite and other polyhydric alcohols was also studied in 1856 and 1857; also the conversion of mannite and glycerine into sugars, properly so called. The esters of pinite, etc., with tartaric acid, were also studied, and in 1858, trehalose and melezitose were discovered. In 1859 Berthelot maintained that the action of yeast is not a vital, but a chemical phenomenon; and he returned again and again to the study of fermentation.

These and other similar investigations on esters led him, in conjunction with Péan de Saint-Gilles, to investigate the rate of esterification; and the experiments, begun in 1861, led to a long piece of work on chemical equilibrium, and on "affinity." In 1869 he attempted to limit the action of hydrochloric acid on zinc by pressure, but unsuccessfully; and in the same year he investigated the equilibrium between carbon and hydrogen, in sparking acetylene under pressure. And later in that year he announced laws, describing the partition of bodies between two solvents, and he investigated the state of equilibrium in solution. In the same year appeared the first of the long series of researches on thermal chemistry. In 1875 he returned to the subject of chemical equilibrium, dealing with the partition of acids between several bases in solution.

Among other syntheses was that of formic acid from caustic soda and carbon monoxide; oxalic acid was produced by the oxidation of acetylene; and acetates, by the slow oxidation of acetylene, in contact with air and caustic potash, in diffuse daylight.

In 1857 the combination of unsaturated hydrocarbons with the halogen acids was studied, as well as the conversion of chloro- and bromo- hydrocarbons into hydrocarbons by reduction. In 1860 ethyl iodide was synthesised by the union of ethylene with hydriodic acid; and in 1867 the use of a concentrated solution of hydriodic acid as a universal reducing agent at high temperatures was discovered.

Berthelot's numerous and important researches on the acetylides of silver and copper doubtless led him to pay attention to explosives. Begun in 1862, they were continued until 1866; and in that year he enunciated the theory that the production of mineral oils may conceivably have been due to the action of water and carbonic acid on acetylides of the alkaline metals, and to the subsequent resolutions of acetylene at a high temperature into other hydrocarbons. These researches on the acetylides were followed in 1870 by investigations on the explosive force of powders, the explosions being carried out in a calorimeter.

In 1871 Berthelot proceeded to investigate the detonation of mixtures of gases, and he made measurements of the heat of formation of nitro-glycerine. In 1874 and 1876 the work was continued; and in 1877 it was extended to the temperatures of explosive mixtures, and to the velocity of combustion. In 1878 explosive mixtures of dust with air, and in 1880 fulminating mercury, were examined. A research on the velocity of the explosive wave in gases followed in 1882; and in 1884 measurements of the specific heats of gases at high temperatures were made. In the same year the calorimetric bomb was invented; and in 1892 it was adapted to the requirements of organic analysis.

Allotropic varieties of the elements also claimed Berthelot's attention. In 1857 he commenced with a study of allotropic varieties of sulphur; and in 1870 he investigated these varieties thermally. In 1869 he examined the allotropic varieties of carbon, and this led him to the preparation of various forms of graphitic oxides. Allotropic silver and other allotropic forms were also the subject of his research.

Berthelot also did much work by help of the "silent discharge." Attracted to it in 1876, when he submitted mixtures of organic substances with nitrogen to its influence, and succeeded in causing the nitrogen to enter into combination, he repeated Brodie's experiments, and reproduced the oxide C_4O_3. In 1878 he produced by the same means the higher oxide of sulphur, S_2O_7, in needles often a centimetre in length, and in 1881 pernitric anhydride. In 1895 he carried out similar work with argon, and later with helium.

From an early date, Berthelot interested himself in agricultural chemistry. From his laboratory at Meudon, assisted by his colleague, André, have appeared a succession of memoirs, chiefly relating to the absorption of nitrogen by plants, and to their behaviour under the influence of electric energy. To the very end his interest was kept up in these experiments; and he was hopeful of increasing by electrical means the productiveness of cereals, and of adding to the world's food-supply.

Though so keenly alive to the present, the past had for Berthelot a great attraction. In 1877 he analysed a sample of Roman wine, which had been preserved in a sealed flask; and he has contributed to the Journals many notices of the composition of ancient objects of metal. His works on "Les origines de l'Alchemie," and on a "Collection des anciens Alchimistes grecs, texte et traduction," and his "Introduction à l'étude de la Chimie des Anciens et du moyen âge" involved long research of ancient manuscripts; he acquired facility in reading ancient Greek, though for Arabian sources he was dependent on others.

Berthelot was the author of numerous works besides those on Alchemy. In 1872 he published a Treatise on Organic Chemistry; a fourth edition appeared in 1899. This was followed by "La Synthèse chimique"; "Essai de Chimie méchanique" (1879), in which he announced the principle of "maximum work," a doctrine afterwards withdrawn, or, at least, greatly modified in 1894; "Traité pratique de Calorimétrie chimique" (1893); "Thermochimie: Données et lois numériques" (1898), in which an account of his long series of calorimetrical measurements is given; this work and that of Julius Thomsen on "Thermochemie" are the standard books on the subject, and each contains the results of the individual researches of its author.

Berthelot's mind was one which interested itself greatly, not merely with things, but with their origins; and in "Science et Philosophie" and "Science et Morale" he treats of the relation of science to human thought. The same critical spirit manifests itself in his "Histoire des Sciences: La Chimie au moyen âge," in which Syrian and Arabian Alchemy is treated of.

A partisan of Lavoisier, "La Revolution chimique de Lavoisier" presents that point of view strongly. He also published his correspondence with Renan in 1898.

The lectures which he delivered at the Collège de France were published under the titles "Leçons sur les Méthodes générales de Synthèse en Chimie organique"; "Leçons sur la thermochimie"; "Leçons sur les principes sucrés"; and "Leçons sur l'isomérie." The application of thermal chemistry to problems of life was treated of in his "Chaleur animale," and in 1901 he published three volumes on "Les Carbures d'Hydrogène."

One point remains to be mentioned. It has sometimes been objected that Berthelot kept science on a wrong path by persistently retaining the old system of representing formulæ, after all the rest of the world had abandoned it. The writer remembers well a conversation in the late '80's, in which Berthelot defended his views. He thought the position of those who employed the customary notation (and, of course, they comprised practically the whole chemical world) not unlike that of the defenders of the phlogiston theory! The retort was obvious, but not made. Berthelot had not even the excuse of Cavendish, who after a calm deliberate statement of the results of his research in terms of the then new hypothesis of Lavoisier re-stated it in terms of the phlogistic method, saying that he preferred to make use of the older and better known language, rather than of the newer modes of expression. For in 1890 Berthelot was, perhaps, the only survivor of the older chemists. Professor Guye, who attended his lectures in 1890–91, tells that the session was begun, as usual, with the special notation of which Berthelot was the sole defender ("equivalents based on two volumes of vapour"), and that, without the slightest warning, in the middle of a "chapitre," to the great astonishment of his audience, he effected the change, dealing with a subject of which the first portion had been expounded in the "equivalent" notation, and continuing in the newer notation of which he had so long been the opponent.

No one is more conscious than the writer that he has failed to do justice to this remarkable personality. His only excuse is that he has done his best. He wishes that it were possible to convey to the reader a sense of the brilliancy, the vivacity, the power, the ability, the talent, and the high character of the great chemist. In the life-like plaquette by Chaplain, his features and his attitude have been admirably reproduced. Truly he was one of the most remarkable of the eminent men of whom France may be proud. He and his wife lie in the vaults of the Pantheon, in life united, in death not put asunder.

W. R.

LUDWIG BOLTZMANN. 1844—1906.

LUDWIG BOLTZMANN was born on February 20, 1844, and was the son of Ludwig Boltzmann, Fin.-Bez.-Kommiss., and Katherina Paurenfeind. He was educated at the Gymnasium at Linz, from whence he proceeded to the University of Vienna. He appears to have been early attached to the study of molecular mathematical physics, for his paper, "Ueber die mechanische Bedeutung des zweiten Hauptsatzes der Wärmetheorie," was read on February 8, 1866, and was thus written at the age of 21. Boltzmann obtained the Doctorate, and became Privat-Dozent, and in 1867 was appointed Assistant in the Physical Institute of the University of Vienna. This Institute, where much of Boltzmann's best work was done, was a large and dingy-looking house in the Türkenstrasse, and formed a striking contrast to the palatial edifices without which no physical department is content nowadays. But, if the bricks and mortar looked uninviting, the brains inside more than made up for the deficiency. In or before 1875, Boltzmann became corresponding member of the Vienna Academy of Sciences, and, about a year later or thereabouts, he obtained a chair at the University of Graz, where he remained till about 1891. In 1876 he married Henrietta von Aigentier, and in 1885 he was promoted from corresponding to ordinary membership of the Vienna Academy. In 1891 he was called to fill a vacant chair at Munich, and four years later was appointed Professor of Physics at Vienna. In 1904 he was called to Leipzig. He was not happy in the new surroundings, and the longing to return to his old University resulted in his stay at Leipzig being an extremely short one—a matter of a few months, we believe. In addition to the duties attaching to the Chair of Physics, the authorities placed a course of outside lectures in his hands, and with this and other work he was able to earn an income of about £800 a year. His election as corresponding Fellow of our Society dates from 1899.

In estimating the value of Boltzmann's work in that branch of mathematical physics with which his name is so intimately associated, it would be a difficult and unproductive task to discuss claims of priority on mere matters of details. The groundwork of the Kinetic Theory of Gases, and in particular the opinion that temperature is a quantity of the same kind as molecular kinetic energy, had of course remained buried in the manuscript of Waterston long before Boltzmann's first paper was published. But while others were working side by side with Boltzmann during a great part of the time that he was publishing his best work, it cannot be said that this concurrence in any way lessened the importance of Boltzmann's work. It is certain that his first paper on the Second Law antedates by several years the first of the Clausius-Szily series of papers on the same subject. If Boltzmann's original proposal to establish that law on a purely deductive basis, and to penetrate beyond the inevitable assumption, which seems to present itself at every step as a bar to further progress, formed the work of a lifetime, certainly Clausius and Szily did not do much, if anything, in attempting to unearth and, if possible, root out the assumption in question. In fact, the assumption underlying the Second Law has been a stumbling block and at the same time a stimulus to progress which has played much the same part in the development of statistical thermodynamics that Euclid's axiom has played in the development of geometry.

In the first place the notion of temperature leads to the conception of a law of partition of energy. Boltzmann was not long in following up in the direction started by Maxwell, and his criticisms and further developments, leading in turn to further work from the pen of Maxwell—Boltzmann was only 24 at the time—must be regarded as striking achievements on the part of two young physicists of that period. Next comes the difficult question of irreversibility, and in the theorem known as Boltzmann's Minimum Theorem we have a remarkable contribution indeed. If any element of chance is assumed to enter into the question of molecular motions, this theorem establishes a definite tendency to a state of energy equilibrium. That it does not dispense with the inevitable assumption is shown by imagining the motion reversed. It is true that this would lead to a highly improbable hypothesis, namely, that the probability of a collision between two molecules depended on their motions after instead of before collision. But even so, the matter is not a question of pure particle dynamics. Later discussions of the minimum theorem viewed in the present aspect have led to an output of much good work on the part of Boltzmann.

A fresh line of thought was opened up by an idea previously suggested by Dr. Oskar Emil Meyer in the application of the theory of probability to problems of statistical dynamics. Boltzmann proved that in a molecular dynamical system if for a single molecule all values of the coordinates and corresponding momenta are *a priori* equally probable, then the most probable distribution in an aggregate consisting of a large number of molecules is the well-known Boltzmann-Maxwell distribution. He also established relations between the probability function and entropy. This method of investigation was applied quite recently to quite a different purpose, namely, the irreversible problems of radiation, by Planck, and, though Planck's book has only been out a short time, it has already received discussion at the hands of Dr. Paul Ehrenfest, of Goettingen. The publication of Helmholtz's paper on monocyclic systems gave Boltzmann another method of attack, and led to a detailed examination of the conditions that a system should be "statistically monocyclic," a point of view which does not seem to have been foreshadowed to any great extent by Helmholtz.

Of other subjects on which Boltzmann wrote, we need only refer to his lectures on Maxwell's electrical and optical theories, his studies of the Lagrangian equations for non-holonomic systems, and his papers on Hertz's experiments.

Boltzmann attended the British Association at Oxford in 1894, and was also present for a short time at the Southport Meeting in 1903, and many English workers were thus brought into personal touch with the Vienna physicist. His visit to Oxford will long be remembered. He was greatly struck with the reception accorded him and, in returning thanks for the foreign guests, he expressed a wish to "often come at England."

Since Boltzmann first came to the front the trend of physical thought has shifted from molecules to the ether, and from the ether to electrons. We have thus come back to kinetic theories, and have merely extended the order of smallness of the particles of which these theories take cognisance. But, while students of reversible phenomena have had fairly straightforward problems to solve, the problem of irreversibility still remains to a great extent a mystery, and nobody seems as yet to have got to the bottom of it. The irreversible phenomena of the universe all have a certain definite trend, and lead to the transformation of energy into certain definite forms. We say that certain forms of energy are less available than others, but why the less available forms are those associated with what are commonly called heat phenomena is a riddle which Boltzmann went far to solve, but which still presents difficulties.

In 1904, on the celebration of Boltzmann's sixtieth birthday, physicists in all parts of the world worked together to honour the occasion by producing as a *Festschrift* a monumental volume dealing with every aspect of physical thought.

The news that Boltzmann had committed suicide while away on his summer holiday last August came as a terrible shock to those who knew him. Of the details of the incident the present writer knows nothing, but surely it suggests several serious reflections. Is it not probable that Boltzmann's ever-active brain had been taxed too heavily by the difficult and elusive problems which he was endeavouring to solve? Mathematical research is a dangerous occupation if carried too far, and the consequences that may have been the result of this intense concentration of thought should prove a warning to others not to allow themselves to be too deeply absorbed in any particular investigation. The difficulty of tearing oneself away from a particular line of work till it has been finished constitutes a grave danger. There are few mathematicians and physicists who would not gladly accept life-fellowships that would enable them to devote their whole time to research, but would they live to do their best work under such artificial conditions? It may be that such obstacles and difficulties as the necessity of undertaking some elementary teaching constitute an analogue to the refrigerator which is necessary for the continuous and efficient working of a thermodynamic engine.

Boltzmann leaves behind him four children, and when last the present writer visited him at Vienna in 1903, his eldest son and daughter were studying for the University. It need hardly be added that the honorary title of Hofrat was conferred on him by the Austrian Government.

G. H. B.

AUGUST DUPRÉ, 1835—1907.

August Dupré was born at Mainz on September 6, 1835, and died at his residence, Mount Edgcumbe, Sutton, Surrey, after some weeks' illness, on July 15, 1907, in his seventy-second year. He was the second son of J. F. Dupré, a merchant and citizen of the then Freie Reichsstadt of Frankfurt-am-Main, and his birth was entered in the register of the "Freie Französische Gemeinde" of that city. On his father's side Dupré traces his descent in a direct line from Cornelius Dupré, a French Huguenot who left France in 1685, after the suspension of the Edict of Nantes, and settled in the Palatinate, and who distinguished himself later as an officer in the army of Prince Eugene. Dupré's mother was also of Huguenot descent. His family was, therefore, originally French, but by intermarriage had become practically German in the course of a hundred and fifty years.

Dupré had a somewhat varied school education which he completed at the Polytechnic schools of Giessen and Darmstadt, and entered as a student of the University of Giessen in 1852, at the age of seventeen. There he studied chemistry under Professor Will, also attending the lectures of Kopp and others. From Giessen he proceeded to Heidelberg in 1854, Bunsen and Kirchoff being among his teachers, and there he finally took his degree of Doctor of Philosophy in 1855, being barely twenty years old. It is interesting to note that fifty years later, in 1905, the University renewed his Diploma (Goldenes Doctor-Jubiläum) in recognition of his scientific work. Among his fellow students at Giessen and Heidelberg who became famous in later life were Harley, Matthiessen, Roscoe, and Volhard.

In the autumn of 1855 Dupré proceeded to London and became assistant to Odling, whom he accompanied to Guy's Hospital, remaining with him till 1863.

In 1864 he was appointed Lecturer on Chemistry and Toxicology at the Westminster Hospital Medical School, in succession to his elder brother, Dr. F. W. Dupré, who had given up the appointment in order to take up mining in the then recently discovered salt deposits of Stassfurt, in connection with which he is now so well known.

August Dupré remained in London for the rest of his life, and became a naturalised English subject in 1866. He resigned his appointment at the Westminster Medical School in 1897, after thirty-three years' tenure, but during the last ten years, owing to pressure of consulting work, he had practically handed over the lectureship to the writer, who was associated with him as Assistant-Lecturer from 1885. From 1897 till his death in 1907 he continued to practise as consulting chemist, both privately and in connection with several Government Departments, at his private laboratory in Edinburgh Mansions, Westminster.

Soon after he left the University Dupré began to publish various scientific papers and, owing doubtless to this fact and the reputation for ability which he enjoyed in his own immediate circle, it was not long before he obtained several other public appointments in addition to the lectureship at Westminster.

Thus in 1871 he was appointed Chemical Referee to the Local Government Board and about this time he was first consulted by Sir Vivian Majendie, then Colonel Majendie, Chief Inspector in the Explosives Department of the Home Office, to which Department he shortly after became permanently attached as Consulting Chemist. In 1873 he became Public Analyst for Westminster, which post he held till 1901. In 1874 he was appointed Lecturer on Toxicology at the London School of Medicine for Women, an appointment in which he always showed the keenest interest and which he held till 1901.

He was also consulted by the Board of Trade, the Treasury and the late Metropolitan Board of Works.

In all these appointments and consultations he may be said to have distinguished himself brilliantly, by his rapid and thorough grasp of the problems in hand, his marked originality, his extreme conscientiousness, his intense enthusiasm, and his infinite capacity for taking trouble. He rapidly rose to eminence.

In 1875 he was elected a Fellow of the Royal Society. In 1877 he became President of the Society of Public Analysts. From 1871 to 1874 he sat on the Council of the Chemical Society. In 1885 he was made a Vice-President of the Institute of Chemistry. In 1886 he was elected Examiner in Chemistry to the Royal College of Physicians, and again in 1892.

In 1888 he was appointed a Member of the War Office Committee on Explosives, in 1891 an Associate Member of the Ordnance Committee, and in 1906 a Member of the Ordnance Research Board.

His earlier work for the Local Government Board, beginning in 1871, was largely analytical, but in 1884, 1885, and 1887 he made a series of investigations in connection with the purification of water supplies by aëration and by the agency of bacteria, which must certainly rank as original researches of high merit and which undoubtedly have assisted greatly in the evolution of the most modern methods of treating sewage. They are published in the Medical Officers' Reports of the above dates, but are probably not widely known in the present day.

In conjunction with Abel, Dibdin, Keates, Odling, and Voelcker he advised the late Metropolitan Board of Works as to the condition of the Thames in 1878, 1882, and 1883, and in 1884 made numerous experiments in conjunction with Mr. Dibdin on the treatment of London sewage on a large scale. This work is referred to at great length in the Report of the Royal Commission on Metropolitan Sewage Discharge in 1884. He was a Member of the Departmental Committee on White Lead in 1893, and gave evidence before numerous other Royal Commissions.

Of all this Government work it was the Home Office appointment which mainly occupied him. When, in 1871, he was first consulted by the Explosives Department, the manufacture in England of dynamite and guncotton had but recently commenced, and these two were practically the only high explosives known at that time. Much had to be done on the part of the Government in connection with the safe manufacture, storage, transport, and use of these explosives, and the rapid development of the industry necessitated the introduction of the Explosives Act of 1875. In 1876 the authorised list of explosives comprised twelve kinds only, but in 1907 it had risen to 182. In addition, during this period, 108 explosives had been passed by the Home Office after examination by Dupré, and over one hundred had been rejected by his advice. He thus investigated, during a period of thirty-six years, nearly four hundred entirely new explosives of the most varied composition, and further examined, at frequent intervals, all explosives imported into England, as to safety. In the course of this work he had often to evolve original methods of analysis or of testing for safety, and in this latter direction, especially, he rendered great services to the Government, and, indirectly, to the public.

It was also part of his duty to assist H.M. Inspectors in investigating the causes of various accidental explosions in factories and elsewhere, which occurred from time to time. His work, therefore, involved heavy responsibilities, and sometimes serious personal risks, notably during the Fenian outrages in 1882–83, when he had to examine several "infernal machines," and on the occasion of the Birmingham scare in 1883, when he superintended and himself assisted in the conversion of several hundred pounds of impure nitro-glycerine (which had been secretly manufactured in the heart of Birmingham) into dynamite, and so averted what might have been a terribly disastrous explosion. He was highly commended in the House of Commons by Sir William Harcourt, then Home Secretary, in connection with this "prompt and courageous action," and by Sir Vivian Majendie in the 8th Annual Report of the Inspectors of Explosives, in 1883. As late as 1907 he devised a new method of testing for infinitesimal traces of mercury in explosive compounds. His private consulting work was also considerable, and he was engaged in many important law cases as a scientific witness.

It might well be supposed that these responsible undertakings engrossed him entirely, but this was far from being the case. During the first twenty years of his appointment at the Westminster Hospital Medical School he gave great attention to his lectures and to the practical teaching of chemistry. His lectures were always very fully illustrated with experiments which year after year seemed to give him renewed pleasure to perform, and although not very easy to follow, he was always extremely interesting owing to the mass of information he had ever ready to hand. In 1886 he published, in conjunction with the writer, then recently appointed Assistant-Lecturer, "A Manual of Inorganic Chemistry," which had some success, and which reached its third edition in 1901. This book was dedicated to Professor Will, of

Giessen, whom he always spoke of with the highest admiration and reverence as a great teacher.

The subject of toxicology, on which, as already said, he also lectured both at Westminster and at the London School of Medicine for Women, had always specially interested him, and he became known and was not unfrequently consulted as a toxicologist. He was brought into particular prominence in connection with the celebrated Lamson case in 1881.

As an instance of the thoroughness of his work, the writer well remembers Dupré tasting sixteen quinine powders which had been prepared for the unfortunate victim in this case, and his almost immediately experiencing the now familiar and somewhat alarming physiological effect of the aconitine which he found in the last powder. He was associated in this case with Sir Thomas Stevenson.

It has already been mentioned that very soon after leaving the University Dupré began to publish scientific papers, and it seems surprising that amid such varied occupations he found time to work out so many original problems. His papers amount to no less than thirty-four in number between 1855 and 1902. Of these, five papers are included in the Proceedings and Transactions of the Royal Society between 1866 and 1872. The first, in 1866, with Dr. Bence Jones, on "Animal Quinoidine," may be said to have anticipated the later important researches of Selmi and others on Ptomaines. Another, in 1871, dealt ably with the Elimination of Alcohol in the human subject, a problem then arousing much interest. The remaining four papers, published between 1868 and 1872, some of the work being done in conjunction with the late Mr. F. J. M. Page, rank, perhaps, as his best efforts, treating of the Specific Heat and other characters of various aqueous mixtures and solutions, notably of mixtures of ethylic alcohol and water, in the course of which he made the remarkable observation that mixtures of these last two substances up to 36 per cent. ethylic alcohol had a specific heat sensibly higher than that of water itself.

In the Journal of the Chemical Society are found eight papers between 1867 and 1880. One on the Synthesis of Formic and Sulphurous Acids, four on the Various Constituents of Wine, including compound ethers, one on the Estimation of Urea with Hypobromite by means of an ingenious apparatus now so universally employed, and two, in conjunction with the writer, on a New Method of Estimating Minute Quantities of Carbon, which was included by the late Dr. E. Frankland in his well-known work on Water Analysis.

Between 1877 and 1883 he read no less than thirteen papers before the Society of Public Analysts, dealing with the analysis of foods or water, and most of the methods evolved by him in these publications are still used or have given rise to improved operations, notably those dealing with butter fat, fusel oil in whiskey and other spirits, alum in flour and bread, foreign colouring matters in wine, and methods of water analysis.

He published only two papers on Explosives, to which he had given such great attention, before the Society of Chemical Industry, and these as late as 1902. As a matter of fact, however, much original work was done by him in this branch of chemistry, some of which appears in the Annual Reports of H.M. Inspectors of Explosives, while again much could not be put forward owing to his official connection with the Home Office.

His earliest papers, published between 1855 and 1862, are six in number, and deal with volumetric methods and spectrum analysis (conjointly with his brother, Dr. F. W. Dupré), the iodic test for morphia and the presence of copper in plant and animal tissues, this last in conjunction with Odling.

To the chemistry of wine, as will be seen from the above summary, he devoted a good deal of attention, and was joint author with Dr. Thudichum of a work entitled "On the Origin, Nature, and Varieties of Wine," published in 1872, in which a considerable amount of original analytical work is embodied.

Dupré married, in 1876, Miss Florence Marie Robberds, of Manchester, and leaves a family of one daughter and four sons, two of whom, Frederick and Percy, are now carrying on his work for the Home Office. He was of a striking personality, of medium height, but very powerfully built, with a massive head and brow, and must have possessed an iron constitution. As a young man he was a skilled fencer and swimmer. He was of somewhat excitable temperament, but had a most kindly disposition. Although not a fluent speaker, he was impressive from his obvious sincerity, and the thorough knowledge he displayed. He therefore made an excellent expert witness, and was more than once complimented in Court on his straightforward evidence. In controversy he was unsparing where facts were concerned, and at times intensely sarcastic.

Although almost wholly devoted to chemistry, his mind found many other outlets. He was a great student of history, and his quite remarkable memory was frequently exemplified in conversation on this subject. He was also exceptionally well read in general as well as in scientific literature, both English and German, and amassed a large collection of books. Among other hobbies he pursued astronomy and photography. His mind, indeed, seems rarely to have been idle, he had a perfect passion for work and, except for a few weeks' holiday annually, he never relaxed. There is little doubt that at one time, about 1891, he overstrained his brain, and was obliged for some months to take a complete rest, which, fortunately, restored him to renewed energy. Like many great men, he was of a modest and retiring nature, and probably but few of his contemporaries have realised the magnitude and variety of the work he accomplished during fifty years of almost unceasing activity.*

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* The Royal Society is indebted for this obituary notice to the kindness of Dr. H. Wilson Hake, who succeeded Dr. Dupré in the Chair of Chemistry at the Westminster Hospital Medical School.—Sec. R.S.

PROFESSOR A. S. HERSCHEL, 1836—1907.

To Sir John Herschel (1792—1871), the only child of Sir William Herschel (1739—1822), twelve children were born, three sons and nine daughters. Alexander Stewart was the fifth child and the second son. He was born during the historical visit of his father to the Cape of Good Hope in 1836, and the bare facts about his life and work may here be given in his own words, from a document preserved among his papers and apparently intended for such use. The careful method of statement in regard not only to the details of his career but also to the document itself—*e.g.*, that it was a "first" copy, and that the label did not extend beyond a "single page"—is thoroughly characteristic of his work and writings. To complete the record, it must be added that he continued to live at Observatory House, Slough, until his death on June 18, 1907; and that he joined the Société Astronomique de France in March, 1897.

First copy of (single page) "Record" label and signature and date, gummed on back of enlarged carbon print "Museum" portrait (by Melhuish), presented to the South Kensington Museum, 1893, by the Amateur Photographic Association :—

Alexander Stewart Herschel.—Second son of the late Sir John F. W. Herschel, Bart. Born in Cape Colony in 1836, and educated at Clapham Grammar School (1851—55) by the late Professor of Astronomy of Oxford University, the Rev. C. Pritchard, F.R.S., etc. ; and at Trinity College, Cambridge (1855—59), and at the Royal School of Mines, London (1861—2—(1865 ?)). B.A. Camb., 1859; M.A. Camb. and (*ad eundem*) Durham, 1877; Hon. D.C.L. Durham, 1886. Became Fellow R.A.S., 1867; Assoc. Liverpool Astronomical Society, 1888; Honorary Member of the North of England Institute of Mining and Mechanical Engineers, 1871 (united in 1889 to the Federated Institute of Mining Engineers), and of the Newcastle-on-Tyne Chemical Society (united in 1883—4 to the Society of Chemical Industry), 1871; Corresponding Member of the Philosophical Society of Glasgow, 1874; F.R.S., 1884; Member of the Physical Society of London, 1889; Life Member of the British Association, 1871; and of the Society of Arts, 1892. Was Lecturer on Natural Philosophy and Professor of Mechanical and Experimental Physics in the Andersonian University of Glasgow, 1866—71; and Professor of Physics and Experimental Philosophy in the University of Durham College of Science, Newcastle-on-Tyne, 1871—86; and Honorary Professor of that Institution since 1886.

Writer of the Reports of the British Association on Luminous Meteors and on the Thermal Conductivities of Rocks, 1861—81; and of various papers relating to Meteors, Meteorology, and Physics in Societies' Proceedings, and in Scientific Journals since 1860.

Present Residence: Observatory House, Slough.
Ipse Scripsit, September 14, 1893. A. S. HERSCHEL.

Of the Clapham school days of Alexander and his brothers a brief note or two have been preserved in the "Memoirs of Professor Pritchard." (A letter written in 1844 refers to the eldest brother, now Sir William J. Herschel.) And in correspondence with Sir John in later years, Pritchard several times refers to his old pupils: *e.g.*, in 1866 he was anxious that Alexander Herschel should undertake the "preparing the catalogue of Sir William Herschel's double stars for publication in the 'Transactions of the R. Ast. Soc.,'" and it seems probable that this plan was carried into effect, though in the printed paper (Mem. R.A.S., vol. 35) Sir John Herschel makes no allusion to his son's help.*

Alexander Herschel was best known for his work on luminous meteors: and due prominence is accorded to this work in his own concise record above given. He was himself a diligent observer, spending long hours in the open in the watch for meteors. His post of astronomical observation at Slough was necessarily different from that of his grandfather: for during the half-century following the death of Sir William, trees had grown up in the garden where his great telescope used to stand; and when four of his grandchildren returned to Observatory House in 1888 (after half a century of occupation by strangers), they found a pleasantly shaded garden, but no horizon visible. Over the wall however, in the kitchen-garden, where Sir William's forges and optical works used to be, there were no trees; and there Alexander Herschel would lie on his back and watch the broad sky for meteors. His observations are contained in a long series of small note-books, and every observation is numbered, starting each new year with unity again. The last observation is dated 1907, February 13. A hasty glance at these books with unskilled eyes suggests that probably there is a great deal of valuable material of which no use has yet been made. But a proper estimate of the value of his work in this field can only be given by a meteor observer; and Mr. W. F. Denning has very kindly written the following notes for inclusion in this notice:—

"Professor Herschel's meteoric work was characterised by its remarkable accuracy, its comprehensive detail and large amount, extending over something like half a century. It not only embraced his personal observations, but comprised the comparison and reduction of a great number of materials sent in to him by various other observers in England and abroad. During a long series of years he collected as many descriptions as possible of the fireballs which appeared from time to time, and calculated their real paths in the atmosphere. Some of the very extensive results which he obtained were published in the Proceedings of the Meteorological Society, Annual Reports of the British Association, Monthly Notices, and Journal of the British Astronomical Association. In determining the real paths of meteors, Professor Herschel frequently had conflicting material to discuss, but no one was so eminently well fitted as he was to investigate such results and base correct deductions upon them. His long experience and sound judgment enabled him to deal effectively with data which another computer would be inclined to reject altogether as incompatible and irreducible.

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* The point has been very kindly verified from a bundle of MS. computations by Miss Herschel.

" As regards Professor Herschel's own observations, chiefly made at Hawkhurst, in Kent, Newcastle-on-Tyne, and Slough, he amassed a very considerable number, and fixed the radiant points of many of the showers to which they belonged, but we believe that he did not publish any complete list of the radiants which he observed from time to time. A number of them, however, were referred to in fragmentary form in one or other of the scientific journals published soon after the observations were made. As a result of long practice, he acquired great precision in noting the flights of individual meteors amongst the stars, and could reproduce them on his charts with unusual fidelity. He observed the great meteoric showers of 1866, 1872, and 1885, and collected together the different values for the positions of radiation, and obtained their mean places. It was from his averaged radiant for the November Leonids of 1866 that Professor Schiaparelli was successfully enabled to found his conclusions on the virtual identity of the orbits of this meteoric stream and Tempel's comet of 1866.

" An important paper by Professor Herschel appeared in the Monthly Notices for 1872, in which he called attention to certain showers presumably connected with Biela's periodical comet, and he pointed out the probability of a recurrence of the shower at the end of November, 1872, advising observers to maintain a watch of the sky at this particular period. His anticipations were realised in a very notable manner by the occurrence, on November 27, of one of the grandest meteoric exhibitions of modern times, which fully substantiated the theory of close association existing between comets and meteors, and certainly demonstrated that the slow meteors returning at intervals at the end of November really represented the *débris* of the lost comet of Biela.

" Valuable work was accomplished by Professor Herschel in the calculation of the radiant points of comets. A complete list of his results forming a valuable summary for reference and comparison was published in the 'British Association Report,' 1875, and in the same volume and also in Monthly Notices, vol. 38, p. 369, he gave lists of known accordances between cometary and observed meteor showers. In collaboration with Mr. R. P. Greg, he formed several catalogues of the radiant points of meteors observed by the British Association members, including one giving 88 positions in 1868, and another of 63 positions in 1875 (British Association Reports, 1868, 1872, 1875). Connected with the Luminous Meteor Committee of the British Association for many years and acting as Secretary, he drew up the lengthy and valuable annual summaries of observations and general facts of meteoric progress which served more than any other cause to advance our knowledge of this branch of Astronomy during the period over which they extended, terminating in 1880. He also furnished the yearly Reports on the progress of Meteoric Astronomy for the Council of the R. Ast. Soc. until they were temporarily discontinued in 1881.

"Professor Herschel's writings were voluminous and marked by a precision and regard for detail which sufficiently showed his desire to omit nothing which could assist in forming correct deductions and serve as useful materials for study by future observers. His own practical work in this field of observation attained a high degree of excellence and others emulated the worthy example he had set. He often extended his watches for shooting stars into the morning hours and was unwearying in his efforts to observe not only the periodical showers, such as those of August and November, but equally endeavoured to trace out the more tenuous and exhausted streams of which the heavens furnish a multitude of examples. He encouraged and instructed other observers and stimulated them to take up work in the meteoric branch, offering, as he pointed out, the prospect of important and interesting discoveries.

"The value of a man's influence upon any branch of research cannot be fully judged from the results he himself accomplished. Professor Herschel by his prolific, agreeable and accurate writings led many others to interest themselves in recording meteors; and a pretty large proportion of the meteoric observations obtained during the last half century may be fairly said to have been initiated by the enthusiasm which he created and fostered in amateurs for this attractive branch of Astronomy."

But though the work on meteors engrossed the greater part of his scientific activity, Alexander Herschel had many other interests, as is testified by his numerous papers and bundles of correspondence. One of the chief of these was photography. His father was a keen and original photographer—the first man, it will be remembered, to use glass as a support for a photographic film (and the first picture he took in this way was of *his* father's great telescope). Alexander's devotion to photography was thus hereditary, and here, again, he not only worked assiduously himself but stimulated activity in others. The presentation of his portrait to the South Kensington Museum by the Amateur Photographic Association is recorded above, and among his treasured possessions was a beautiful album of photographs presented to him by the Newcastle-on-Tyne and Northern Counties Photographic Association (of which he was President, 1885—7) as a "slight acknowledgment of services rendered."

But his interests were wide and varied: plane waves, hedgehogs, astronomy, engineering; there is a large bundle of papers on fans for ventilation of mines, and another relating to a correspondence in 'Nature' with Professor P. G. Tait, in 1883, on the "Matter of Space." In 1900 he wrote for 'Nature' a long and careful review of the work of Piazzi Smyth in spectroscopy. His brother, Colonel J. Herschel, has remarked on his extraordinary vitality; he nearly always *ran*, rather than walked, to his miscellaneous occupations and, however unexpectedly he might thus come across another member of the family, or an acquaintance, his alert mind prompted instantly some appropriate remark. But his mental activities had two unfortunate results: he shunned the interruptions of society so far as to become practically a recluse, taking all his meals alone, and he became impatient of his bodily needs until the neglect of them shattered his health. He died on June 18, 1907, at the age of 71, and on June 22 was buried in the grave at St. Laurence's Church at Upton, where his famous grandfather had been laid eighty-five years before.

H. H. T.

ADMIRAL SIR LEOPOLD McCLINTOCK, K.C.B., F.R.S., 1819—1907.

WITH Sir Leopold McClintock we lose the chief leader and organizer of the Franklin searches. In experience of Arctic navigation and wintering he was second only to Sir James Ross. That great navigator was in the Arctic and Antarctic Regions during nineteen summers and eleven winters. McClintock experienced eleven navigable seasons and six winters. Parry, who comes next, had nine navigable seasons and four winters. Excepting some of Parry's companions, no other Arctic explorer approaches the record of these three, James Ross, McClintock, and Parry. As regards sledge travelling without the help of dogs, McClintock stands first, and will remain first, probably, for all time.

Francis Leopold McClintock was of a Scottish family, settled in Ulster in the early part of the seventeenth century, his father being the youngest son of John McClintock of Drumcar, co. Louth. His mother was the daughter of Dr. Fleury, then Archdeacon of Waterford, of an old Huguenot family from near Rochelle. The Archdeacon's wife was English. Leopold, the second son of a family of fourteen, was born at Dundalk on July 8, 1819. Through the interest of a cousin, who was first lieutenant of the "Samarang," a 28-gun frigate, young McClintock entered the navy before he had reached the age of twelve. During his seventeen years of sea service before entering upon his Arctic career, three things probably combined to stimulate his interest in a noble profession, and to form his character as a trustworthy officer and a thorough seaman. The first was his severe and arduous work in a surveying vessel in the Irish Sea. The second was his position as a junior commissioned officer when the paddle steamer "Gorgon," commanded by Captain Charles Hotham, was driven high and dry on the beach at Monte Video while a furious *pampero* was blowing. The skill and ingenuity with which Captain Hotham succeeded, with the zealous co-operation of officers and men, in floating the vessel after several months, was looked upon as one of the finest feats of seamanship of the century. The details were described, in a book entitled "The Floating of the Gorgon," by Cooper Key, one of the lieutenants, who was eventually a Fellow of this Society. Soon afterwards the Commodore of the Station placed an acting lieutenancy at the disposal of Captain Hotham, and he at once gave it to young McClintock. This may be considered as a proof that the future Arctic explorer was amongst the most useful and zealous of those who were concerned in that famous and difficult feat in seamanship. The third event was McClintock's appointment as Third Lieutenant of H.M. brig "Frolic," in the Pacific. After a service of upwards of a year up the Gulf of California, McClintock became the First Lieutenant of the "Frolic," when he brought his knowledge, acquired under Sir Charles Hotham, to bear in raising a wreck in the Straits of Magellan. An English brig had been burnt and sunk in the anchorage of Punta Arenas. The officers and crew of the "Frolic" were employed for about three weeks in raising the vessel out of the anchorage, a difficult piece of work which was successfully performed. The wreck was placed on the beach, and specie to the value of £9000 was recovered. Her own crew had disappeared long before.

After the "Frolic" was paid off in June, 1847, McClintock went to study at the R.N. College at Portsmouth. Alarm was beginning to be felt at the long absence of Sir John Franklin's expedition, and two vessels, the "Enterprise" and "Investigator," were ordered to be fitted out under the command of Sir James Ross, to obtain tidings and bring relief. At that time Captain William Smyth, the second naval officer who ever descended the whole course of the River Amazon, was at the College, and was a friend of Sir James Ross. It was through Smyth's recommendation that McClintock was appointed Second Lieutenant of the "Enterprise." She was a sailing ship of 470 tons, with no auxiliary steam power. Sir James fully expected to meet his friends Franklin and Crozier in Barrow Strait, coming home. But it turned out far otherwise. It was a very close ice year, and Ross's vessels were obliged to winter in Port Leopold, at the N.E. end of North Somerset, having obtained no tidings of the missing expedition.

In the spring of 1849 Sir James Ross made a sledge journey of forty days, starting on May 15, which was then considered a sufficiently early date. He was accompanied by McClintock. He examined 500 miles of coast, most of it previously unknown, and his journey was the longest that had hitherto been made. But there were grave mistakes. The diet was quite insufficient, and the sufferings and privations were great. All the men were quite exhausted when they returned to the ship, and were laid up for weeks. The winter arrangements were defective, there was sickness and several deaths, and scurvy was in the ships when they returned to England in the autumn of 1849.

McClintock saw all the mistakes, and the way to avoid them in future. But the main result of his first Arctic voyage was his perception of the great future of sledge travelling. He saw that the work of the ship was to bring explorers to the threshold of their achievements, but that the actual discoveries must be made by sledges over the ice. He, therefore, devoted some months to a close study of the problems to be solved. The scale of diet must be improved, so as to keep the men strong and healthy, while the closest attention must be given to a reduction of the weights to be drawn. He also made experiments, with the assistance of Professor Samuel Haughton, on the best cooking apparatus, and on the rate of consumption of different kinds of fuel. The best clothing for Arctic sledging work also occupied his attention.

At this time McClintock had just reached his thirtieth year. With a short, lithe figure, and a well knit frame, he was well adapted for long-sustained endurance of hardships and fatigue. He had a genius for organisation, and was gifted with inventive faculty and a quick perception of the exact thing that was needed in an emergency. Though reticent, he took an interest in conversation, and was well informed. His manner was very quiet, but his firmness and resolution obtained for him the confidence and devotion of those who served under him. Always perfectly calm, he gave his orders in an emergency with decision, but without noise. He was a sympathetic friend and an excellent messmate.

The return of Sir James Ross without any tidings aroused the country. The "Enterprise" and "Investigator," with the "Plover," were sent to Bering Strait. Another expedition, commanded by Captain (afterwards Sir Horatio) Austin, was fitted out, to proceed by Baffin's Bay and Barrow Strait, consisting of two sailing vessels, the "Resolute" (Captain Austin), and the "Assistance" (Captain Ommanney), with two screw steam tenders, the "Pioneer" (Lieutenant Sherard Osborn), and the "Intrepid" (Lieutenant Cator). Two brigs, under Captain Penny, also went out to co-operate in the search.

McClintock was appointed First Lieutenant of the "Assistance," and the expedition left England in May, 1850. Captain Austin had served as a lieutenant with Sir Edward Parry in his third Arctic voyage. It was due to him that the ships under his command were perfectly well ventilated, dry, and comfortable. McClintock always gave Captain Austin the credit for the perfect winter arrangements, and for keeping the officers and men employed and amused. Austin certainly had a genius for detail, combined with warm sympathy and care for the welfare of those under his command. He was too old for sledge travelling, but for winter organisation he was unequalled.

But if McClintock justly gave this credit to Sir Horatio Austin, he himself was perfect as an Arctic First Lieutenant. The expedition was obliged to winter in the pack between Griffith and Cornwallis Islands, officers and men emerging from the long night in sound health, strong, cheerful, and full of zeal. This was due to McClintock as regards the "Assistance," which was the happiest and healthiest ship that ever wintered in the Arctic Regions.

Captain Austin wisely entrusted the arrangements for sledge travelling to McClintock. No record had been found at Franklin's first winter quarters at Beechey Island, and there was, consequently, no clue to indicate the direction the missing ships had taken. It was necessary to organise searches in every direction. This was possible, because there was assembled, in the spring of 1850, by far the largest body of men that ever acted together in the Arctic Regions, and probably ever will. No less than eight extended sledge parties were despatched in different directions, each with a depôt party, and every three with an auxiliary party. This great scheme was due to the genius of McClintock. He introduced the system of autumn travelling to lay out depôts, and of spring depôt and auxiliary parties to enable the extended parties to double their distances. He it was who planned the scale of diet best calculated to keep the men healthy and strong, and all the other arrangements for their comfort, while keeping the weights down to a minimum.

McClintock's own journey to Melville Island in 1851 covered the unprecedented distance of 800 miles. He was away eighty days from the ship, and his men came back in perfect health. It was a memorable triumph. All the other "Assistance" parties carried out their instructions and returned, having suffered nothing but from frost bites and snow blindness. It was a thoroughly well-conducted expedition. When the four vessels returned to Woolwich it was resolved by the Admiralty to send them out again. One division, consisting of the "Resolute" and "Intrepid," was to proceed to Melville Island, mainly with the object of relieving the "Investigator," some anxiety being felt owing to her long absence. This object was happily effected. The "Resolute" and "Intrepid" passed the winter of 1852—53 at Dealy Island, off the coast of Melville Island. McClintock did not fail to make provision for the winter amusements of the men. He felt its importance, although his temperament did not admit of his joining personally in anything but the actual arrangements.

In the severe autumn travelling of 1852, McClintock surpassed himself. He was away forty days, and laid out a depôt at a distance of 260 miles. His spring travelling in 1853 was the greatest achievement, with men alone, that has ever been done, and it remains unsurpassed. He started on April 4 and returned on July 13, being away 106 days, covering 1328 statute miles at a rate of 11 miles a day, and discovering 886 miles of new land, including the northern half of Prince Patrick Island.

The "Resolute" had a team of dogs, procured in Greenland, and they were found useful for keeping up communications. But for such a journey as McClintock made, and over such ground, British seamen are superior to dogs, and will always secure better and greater results. This memorable journey of 1853 proves the thorough efficiency of all McClintock's equipments, down to the minutest detail. He everlooked nothing.

The "Resolute" and "Intrepid" left Dealy Island in August, 1853, but were stopped by the ice in November, and forced to pass a second winter.

The officers and men did not return to England until the autumn of 1854. McClintock had been promoted to the rank of Commander on the return of Austin's expedition, and on his return in 1854 he received his rank of Captain.

His frequent applications failed to obtain for him the employment he had a right to expect during the Crimean War; but at last the crown of his Arctic labours was at hand. In 1857 news arrived that relics had been found amongst Eskimo, proving that the coast of King William Island was the direction that the search ought to have taken. The Royal Society took the lead in submitting a numerously-signed petition urging the Government to complete the search by sending a small and inexpensive expedition in that direction. The Government declined. Then Lady Franklin nobly came forward, and resolved to equip and despatch such an expedition at her own expense. She offered the command to McClintock, who promptly accepted, on April 18, 1857. The small steam yacht "Fox," of 177 tons, was bought and fitted out; the Admiralty supplying pemmican, ice gear, winter housings, chronometers, charts, and warm clothing. The President and Council of the Royal Society voted £50 for the supply of magnetic and other instruments. Besides McClintock, the officers were Lieutenant Hobson, who had served in the "Plover," Captain (now Sir Allen) Young, of the Mercantile Marine, who contributed £500 towards the expenses, and the surgeon, Dr. David Walker. The crew consisted of twenty-four souls, of whom seventeen had already served in the Arctic Regions.

The "Fox" was unfortunately caught in the Melville Bay ice, and forced to pass the winter drifting down Baffin's Bay and Davis Strait. In the spring she broke out during a gale of wind, with huge masses of ice plunging about and crashing against each other in a heavy sea. The ship was for some time in extreme peril. But instead of seeking a port for rest and refreshment, McClintock calmly turned the head of his little vessel once more Northward Ho! Taking his old friend Carl Petersen on board in Greenland, with a team of dogs, he reached Beechey Island and erected Lady Franklin's memorial to her husband and his companions. He then made his way down Prince Regent's Inlet, and wintered in a bay, which he named Port Kennedy, on the north side of Bellot Strait.

By his famous spring journey round King William Island, McClintock obtained many relics from the Eskimo as well as statements. He found that the Franklin Expedition had discovered the continuance of sea between the Atlantic and Pacific; he collected a great number of memorials and relics; and by finding the record at Point Victory, he discovered the fate of Franklin.

Hobson had previously been over the ground on the north shore, and Allen Young made an important discovery along the southern coasts of Prince of Wales Island. The engines of the "Fox" had been partly taken to pieces for the winter. The engineer died, and the two stokers knew nothing about the engine. It is another instance of McClintock's mechanical knowledge and skill that, with his own hands, he put the engine together and got it into working order.

On the return of the "Fox" in September, 1859, McClintock's reception was most cordial. The Admiralty ordered that his time in the "Fox" was to count as service in a man-of-war. He received the honour of Knighthood, honorary degrees of Oxford, Cambridge, and Dublin, the Freedom of the City of London, and of the Grocers' Company.

His modest but excellent narrative of the voyage of the "Fox" went through several editions, and the last one of 1882 has been stereotyped.

McClintock's next service was again in the Arctic Regions, and it was a most arduous one. He received command of the "Bulldog," a paddle-wheel steamer, wholly unadapted for service in the ice. He was to carry a line of deep-sea soundings from the Faroë Islands to Iceland, Greenland, and Labrador. Furious gales were encountered and, after tremendous work among the ice, with paddles bent and floats smashed, the "Bulldog" reached Godthaab in Greenland. The difficult task was eventually completed, and the "Bulldog" returned safely, though she was more than once in danger, needing the calmness, presence of mind, and consummate seamanship of such a man as McClintock for her safe navigation. Dr. Wallich was the naturalist of the "Bulldog." This scientific voyage completed McClintock's Arctic work, and in 1865 he was elected a Fellow of the Royal Society.

Sir Leopold's Arctic services had for their objects the relief of his missing countrymen, and, later, the discovery of their fate. He worked in the cause of humanity. Still, he never lost sight of the interests of science, and missed no opportunity of furthering them whenever he was able to do so. His extensive geographical discoveries did not consist of land merely seen from a ship, but of coasts traversed on foot and closely examined. His collection of miocene fossils from Atanakerdluk, obtained from the Inspector of North Greenland, was a valuable addition to Professor Heer's enumeration of the forest plants of the miocene age in that region. He enabled Professor Haughton to prepare the geological map and memoir of the Parry Archipelago, and the note on tidal streams, which form appendices to the voyage of the "Fox." And the North West Passage! The discovery of a continuous sea from the Atlantic to the Pacific by Franklin, by M'Clure, by Murray Parkes, was not the discovery of a *passage*. On the contrary, Professor Haughton has explained the reasons why a *passage* by any of those routes is impossible. With this knowledge, McClintock pointed out that the only *passage* is by the channel between King William Island and Boothia; and that, in a favourable year, there is no difficulty in passing through it. Sir Allen Young attempted it in a bad ice year in 1875, and the gallant Norwegian seaman, Amundsen, has completed the passage quite recently. McClintock, by the light of Professor Haughton's note on tidal streams, first pointed out the only possible North West Passage. Sir Leopold's last service to science, before his election as a Fellow of this Society, was his command of the "Bulldog."

He continued to serve his country afloat for many years. He had the "Doris" frigate in the Mediterranean, the "Aurora" in the West Indies, and was next appointed to the "Aboukir," as Commodore, at Jamaica. Returning home in 1869 he stood for Droghéda at the request of the Carlton Club, but was unsuccessful. Soon after becoming a Rear Admiral, he was appointed Admiral Superintendent of Portsmouth Dockyard from 1872 to 1877, where he fitted out the Arctic Expedition of 1875. Sir Leopold was next Commander-in-Chief on the North American and West Indian station from 1879 to 1883. On his return he was elected an Elder Brother of the Trinity House, and continued to be an active member of that important Corporation for many years. In 1890 he was created a Knight Commander of the Bath.

In 1870 Sir Leopold had married Elizabeth Annette, daughter of Mr. Dunlop, of Monasterboice House, and of a daughter of Viscount Ferrand and Viscountess Massereene in her own right. He leaves a widow and five children, three sons and two daughters.

Sir Leopold McClintock continued to work, so far as the increasing infirmities of old age would admit, until the end of his long and useful life, which took place after he had reached the age of eighty-eight. He died on November 21, 1907. The illustrious explorer has left a name which is revered and honoured in every civilized country, and his loss will long be mourned alike by his surviving old shipmates and by many newer friends and admirers.

C. R. M.

HENRI MOISSAN, 1852—1907.

Henri Moissan was born in Paris, on September 28, 1852. His father was a native of Toulouse; his mother, whose maiden name was Mitelle, was of an Orleans family. Moissan's features and his bright vivacious manner betrayed his southern origin; he was of the best French type.

His education, after school life, began in the Collège de Meaux; and in his twentieth year he entered the laboratory of Frémy at the Musée d'Histoire Naturelle, attending at the same time the lectures of Henri Sainte-Claire Deville, and Debray. He made good progress and, after spending a year at elementary work, he removed to the neighbouring laboratory of Decaisne and Dehérain, in the École Pratique des Hautes Études, with whom he worked on chemical problems bearing on vegetable life. While there, he passed the examinations required for graduation, taking the preliminary degree of Bachelier in 1874; of Licencié in 1877; in 1879 he became "Pharmacien de première Classe"; and in 1880 he qualified as "Docteur ès Sciences physiques."

After working with Dehérain for little more than a year, he left the Museum to direct a small laboratory of his own; and he then abandoned the study of vegetable chemistry for that of inorganic chemistry, a branch to which he remained faithful for the rest of his life, and in which he achieved the highest distinction. This private laboratory was given up somewhat later; and he then found quarters with MM. Debray and Troost, in the laboratories of the Sorbonne.

In 1879, he was appointed "Répétiteur de Physique" at the Agronomic Institute; and after spending a year in that position, he was promoted to the post of "Maître de Conférences" and "Chef des Travaux Pratiques," or lecture assistant and senior demonstrator at the École Supérieure de Pharmacie, a position which he held till 1883. A year before this change, he had been appointed, after a competitive examination, "Agrégé des Sciences physiques-chimiques," and his standing among his fellows at that date was such that on the death of Professor Bouis, in 1886, he was elected to the Professorship of Toxicology in the School of Pharmacy; he retained that chair till 1899, when his turn came in rotation to occupy the chair of "Mineral" or Inorganic Chemistry; he then for the first time delivered a course of lectures on that branch of Chemistry.

In 1900 he was appointed Assessor to the Director of the School; and in the same year, on the death of Professor Troost, the Professor of Inorganic Chemistry in the Faculté des Sciences in the University of Paris, Moissan was unanimously chosen as his successor, for his name had become very widely known owing to his remarkable discoveries. At the same time he retained the title of Honorary Professor at his old school, the École de Pharmacie.

Moissan's first research was conducted in conjunction with Dehérain; it had reference to the interchange of oxygen and carbon dioxide in the leaves of plants which had been exposed to the subdued light of a darkened room.

His first work in the domain of inorganic chemistry dealt with the oxides of the iron group of metals, and especially with compounds of chromium. His thesis for the doctorate contained an account of a portion of this research. In it he described the existence of two allotropic modifications of chromium sesquioxide: one obtained by igniting ammonium chromate, as well as by other methods, insoluble in acids, unattacked by hydrogen sulphide and by oxygen; the other, produced by careful drying of the hydrated oxide at 440°, which, when heated to 140° in a current of hydrogen sulphide, gave a black Cr_2S_3, reducible to CrS by further heating in a current of hydrogen. Oxygen converted this variety of sesquioxide into the analogue of manganese dioxide, CrO_2, a dark grey powder.

This train of thought led Moissan to investigate the products of reduction of the oxides of the iron group. The so-called "pyrophoric iron," obtained by heating ferrous oxalate, was shown to consist of ferrous oxide, FeO; the same substance is produced by reducing the sesquioxide, Fe_2O_3, in a current of a mixture of carbon dioxide and hydrogen. The action of hydrogen at 330° to 440° reduces Fe_2O_3 to Fe_3O_4, and the magnetic oxide is also formed by heating the sesquioxide in a current of carbon monoxide at the temperature of melting zinc. It is only at 500° to 600° that ferrous oxide is produced; it is pyrophoric at ordinary temperatures. But pyrophoric iron itself can be obtained by heating the sesquioxide for a long time in a current of perfectly dry hydrogen to 440°, or by distilling away the mercury from an amalgam of iron.

An allotropic variety of magnetic oxide, Fe_3O_4, was produced by heating the monoxide, or metallic iron reduced by hydrogen, to redness in a current of moist hydrogen. It formed a black magnetic powder, incandescing and changing to Fe_2O_3 when heated in air. At 1500°, Fe_2O_3 gave off oxygen, and was converted into a very resisting modification of the magnetic oxide.

Somewhat similar researches were carried out on the oxides of manganese, nickel, and cobalt, and pyrophoric varieties of the metals were prepared.

Having obtained metallic chromium from its amalgam, Moissan next investigated the little-known chromous salts, preparing pure chromous chloride, $CrCl_2$; also the blue sulphate, $CrSO_4.7H_2O$, which is amorphous with copperas; chromous acetate, chromous bromide, and chromous oxalate. The acetate or the chloride, on treatment with a solution of potassium cyanide, gave the interesting compound $K_4CrC_6N_6$, analogous to yellow prussiate of potash, oxidisable to the red $K_3CrC_6N_6$. A final paper on the blue compound of CrO_3 with peroxide of hydrogen, in which it was shown that the ratio between the two is $CrO_3 : H_2O_2$, ends the series.

In 1884, Moissan turned his attention to the investigation of compounds of fluorine. He prepared phosphorous fluoride first, by heating copper phosphide with lead fluoride. It is a gas, exploding when sparked with oxygen, and yielding POF_3. He next prepared fluoride of arsenic, by distilling a mixture of arsenious oxide, sulphuric acid, and calcium fluoride. He electrolysed this liquid, and produced from it elementary arsenic, and a gas which attacked the platinum electrode. On submitting phosphorous fluoride to a rain of sparks, phosphorus was deposited; the product, however, was not fluorine, but PF_5, the liberated fluorine combining with the phosphorous fluoride. These researches occupied him until 1888. In that year he investigated some organic fluorides, obtaining C_2H_5F by the interaction of ethyl iodide and silver fluoride, and the corresponding methyl and isobutyl fluorides. In the following year he made the capital discovery that while the compound KF.2HF melts at 65°, KF.3HF remains liquid at $-23°$, and conducts electricity electrolytically. And this long series of researches culminated in the discovery of elementary fluorine.

During this work he accumulated useful information, which enabled him to adapt his apparatus to the end he had in view. One method which he attempted for the isolation of fluorine was to pass phosphorous and phosphoric fluorides over red-hot platinum sponge. A gas was evolved, which liberated iodine from a solution of potassium iodide; but this gas came off very slowly, and was absorbed largely by the platinum tube in which the experiment was made. He next tried the electrolysis of arsenious fluoride; but he found that that liquid is a very poor conductor, and he attempted to increase its conductivity by the addition of anhydrous hydrofluoric acid; better results, however, were obtained on addition of anhydrous potassium fluoride to the mixture of arsenious fluoride and hydrofluoric acid; and from this it was but a step to omit the arsenious fluoride and to electrolyse the mixture of acid and potassium salt.

His first apparatus was made of platinum; the electrodes were rods of platinum-iridium alloy, thickened at the ends, so as to last longer; for the negative electrode was always rapidly corroded. Paraffined corks closed the ends of his first platinum U-tube. The cork closing the limb into which the negative electrode passed was corroded and charred; hence, in his next experiment, corks were replaced by fluorspar stoppers, cemented into hollow platinum cases on which a screw was turned, so that the stoppers could be screwed tight into the two open ends of the U-tube. This experiment was successful in yielding fluorine; while hydrogen came off from the positive electrode, and passed out through a side branch of platinum tube, fluorine was evolved at the negative pole; it passed out through a similar platinum tube, and was made to play on various materials, exposed to its action in a platinum capsule.

It was found that sulphur, selenium, and tellurium inflamed, giving white deposits; the first combines, as Moissan subsequently found, to form a gas, SF_6. From phosphorus, PF_3 and PF_5 were obtained; iodine caught fire and burned; Moissan subsequently found that IF_5 was the product; bromine lost its colour, and again Moissan and his pupils proved this to be due to the formation of BrF_3; on pure carbon at ordinary temperature fluorine had no action; but both boron and silicon caught fire and burned, giving SiF_4 and BF_3.

By blocking the exit of either of the tubes conveying away the hydrogen or the fluorine, one or other gas could be caused to pass round the bend and mix; when a bubble passed round, a detonation occurred, showing that hydrogen and fluorine combine even in the dark at the low temperature of −35°, for the apparatus had to be maintained at this low temperature to prevent the admixture of gaseous hydrofluoric acid with the fluorine. The low temperature was conveniently attained by surrounding the U-tube with liquid methyl chloride.

Most metals were instantly attacked, some with inflammation; even platinum and gold could not resist its action; but they had to be raised to 400° before action took place. Salts such as potassium iodide, mercuric iodide, and lead iodide were completely decomposed, giving fluorides both of the metal and of the iodine. Chlorine was liberated from potassium chlorate, along with oxygen, on which fluorine had no action; chlorine was also evolved from carbon tetrachloride, the tetrafluoride being formed; and water was instantly decomposed, its oxygen being liberated as ozone.

Although all these properties of this gas could be most easily explained on the assumption that it consisted of fluorine, still they might conceivably appertain to a mixture of ozone and hydrofluoric acid, or to a perfluoride of hydrogen, HF_n. The former supposition was disproved by trying the action of such a mixture; but none of the properties of the gas were manifested. The second hypothesis was also disproved by leading the fluorine over iron and proving that no hydrogen passed on.

Subsequent research showed that the formation of fluorine was not so simple as had at first been supposed. Investigation of a muddy deposit, which was always found at the bend of the U-tube on dismantling it, showed that that substance consisted mainly of the compound K_2PtF_6; and that in all probability it was the substance undergoing electrolysis; the equivalent of the potassium being liberated at the cathode as hydrogen, and fluorine at the anode, the group PtF_4 again combining with potassium fluoride. The operation did not proceed with regularity until a considerable quantity of platinum had dissolved from the anode.

The density of the gas was found to be 18·3, on the hydrogen standard. But this figure, which is too low, was almost certainly due to the presence of oxygen, produced by the electrolysis of water still dissolved in the electrolytic mixture. Moissan for long supposed that, on passing the current, the water accidentally present first underwent electrolysis, before the fluorine appeared; but it was subsequently found that water still remained to be electrolysed, even after much fluorine had been separated. Later experiments, in which the gases other than fluorine were estimated in the gaseous mixture weighed, and allowance was made for their presence, proved that the true density of fluorine is 19, a figure identical with the atomic weight. The supposition that fluorine consisted partly of monatomic molecules mixed with an excess of diatomic molecules had therefore to be abandoned. The activity of fluorine was not to be explained by its monatomicity.

The reason why fluorine cannot be produced by heating PtF_4, tetrafluoride of platinum, was found as soon as that substance was prepared by the action of fluorine or platinum; it is because that compound decomposes water, and therefore cannot be prepared in the wet way.

Moissan also attempted to induce combination between argon and helium and fluorine, but without success, even when the mixture was submitted to discharge of powerful sparks.

The preparation of two gaseous fluorides of carbon led Moissan to attempt to remove the fluorine, in the hope that the carbon would be liberated in the form of diamond. But this hope was disappointed; the product was always lamp-black. The experiments led to the discovery of the method of preparing the diamond artificially; it had been found that a meteorite from Cañon Diablo, consisting, as meteorites usually do, mainly of metallic iron, had imbedded in it small crystals of diamond; and Moissan's genius led him to divine the cause of their formation; his theory was that the carbon had originally been dissolved in the iron, when it was in a molten state; that the surface of the iron had suddenly cooled; and that the iron in the interior, on solidifying, was subjected to great pressure; for solid iron containing carbon in solution occupies a larger volume than molten iron. These considerations directed his experiments, which were crowned with success.

His first experiments, in which the iron was saturated with carbon at about 1000°, were, however, not successful; he accordingly argued that at higher temperatures the solubility of carbon in iron should increase, as is the general rule; and he devised the electric furnace to attain much higher temperatures. His three great investigations are seen thus to hang together; one suggested the other, and Moissan's skill and patience brought them all to a successful conclusion. The spirit in which he carried out his work is well expressed in his own words, which occur in the preface to his book on the "Electric Furnace":—"But what I cannot convey in the following pages is the keen pleasure which I have experienced in the pursuit of these discoveries. To plough a new furrow; to have full scope to follow my own inclination; to see on all sides new subjects of study bursting upon me; that awakens a true joy which only those can experience who have themselves tasted the delights of research."

Moissan's electric furnace, designed not for technical but purely for experimental work was of the simplest construction. It consisted of a rectangular block of lime, made of the excellent Paris limestone, in the centre of which a hole had been scooped. This block was covered with a rectangular lid; two grooves of circular section admitted the carbon poles which served as electrodes, and an arc was made between the poles. Later, an electromagnet was used to deflect the arc downwards, so that it might play more directly on the object to be heated. A current of 100 to 125 ampères, at 50 or 60 volts, was employed in his earlier researches.

The volatilisation of the material of the crucible, lime, was the first fact to be chronicled. Indeed, two torrents of what appeared to be flame poured out through the holes admitting the electrodes. These apparent flames were, however, only white-hot lime dust, condensed from the lime-vapour which filled the furnace. Subsequently, to save cost, the body of the furnace was constructed of limestone. The crucible to be heated stood on magnesia, to avoid the rapid formation of calcium carbide; and, for some purposes, crucibles were constructed of a grid of alternate slices of carbon and magnesia. By heating an inclined carbon tube in the arc, and feeding in at one end a mixture of an oxide such as chromium oxide and carbon, the metal flowed out at the other end, and a continuous supply was thus obtainable.

The temperature of such electric furnaces appeared to depend on the quantity and intensity of the current; but it is limited, no doubt, by the temperature of volatilisation of carbon.

By help of this powerful engine of research, Moissan succeeded in causing many changes to occur, and in producing many compounds previously unknown. Some of these compounds have had important commercial applications; others are of great interest, owing to the reactions which they undergo, and the light that they shed on the problems of chemical combination.

Among the products of the electric furnace were:—Crystallised lime, strontia, baryta, and magnesia; distilled copper, silver, platinum, tin, gold, iron, and uranium; volatilised carbon and silicon, and many other similar products. Carbides of the metals of definite composition and properties were often formed; thus from aluminium, Al_4C_3 was obtained in yellow crystals, giving pure methane on treatment with water; in many cases excess of carbon crystallised out in the form of graphite as the metal cooled.

In his systematic search for a method to produce artificial diamonds, Moissan investigated numerous varieties of graphite; he subjected varieties of carbon to the intense heat of the electric furnace, in order to study their behaviour and, as before remarked, he studied the Cañon Diablo meteorite, in which small diamonds are imbedded. These researches made him familiar with the behaviour of carbon under all possible circumstances, and enabled him to separate diamonds from other materials with which they might be mixed.

The first actual experiment of crystallising carbon under pressure from iron was made with 200 grammes of Swedish iron, fused in the electric furnace for six minutes with sugar charcoal in a carbon crucible. The crucible was then seized with tongs and plunged into a vessel full of cold water. Moissan relates the anxiety with which this was first attempted; an explosion was feared; but, although the water boiled, no accident occurred then, nor, indeed, during some hundreds of similar experiments. The iron was dissolved in dilute hydrochloric acid; the residue, chiefly consisting of carbon in various forms, was extracted with nitro-hydrochloric acid, and alternately with boiling sulphuric and hydrofluoric acids. It was then, in order to remove graphite, boiled with nitric acid and potassium chlorate. The final residue was "floated" in bromoform, in which some transparent dust, of density 3 to 3·5, sank, while a black substance floated. The transparent particles scratched ruby, burned to carbon dioxide, and showed octahedral facets.

Among the products of the electric furnace in Moissan's hands must be mentioned metallic chromium, manganese, molybdenum, tungsten, uranium, vanadium, zirconium, and titanium; and carbides of lithium, calcium, barium, strontium, cerium, lanthanum, yttrium, thorium, aluminium, manganese, and uranium. Moissan studied the action of water and acids on these new compounds, and determined the proportions of hydrogen and hydrocarbons which they yielded. He also prepared silicides of iron, of chromium, and "carborundum," now the trade name for carbide of silicon; as well as borides of iron, carbon, and the metals of the alkaline earths.

These researches were described in two works, 'Le Fluor,' published in 1887, and 'Le Four Éléctrique,' published ten years later. Since that date, Moissan's chief researches are as follows:—The preparation of calcium by heating calcium iodide with sodium; its success depends on the easy attack of sodium by alcohol, while calcium is hardly affected; sodium ammoniums and methyl ammoniums, obtained by the action of sodium on liquid ammonia and on methylamine; similar bodies obtained from lithium and calcium; the hydrides of calcium, sodium, and potassium, in a memoir concerning which he shows that these bodies are non-conductors of electricity, and that the hydrogen must be considered to be a non-metal; in later papers he describes a most ingenious formation of sodium formate by the action of carbon dioxide on sodium hydride; and of sodium hyposulphite, $Na_2S_2O_4$, by treating the hydride with sulphur dioxide.

Moissan did not, however, desert his old favourites, fluorine and the products of the electric furnace; for in later years he prepared thionyl fluoride, SOF_2, and sulphuryl fluoride, SO_2F_2, both gases; and he redetermined the density of fluorine in a dry glass vessel. The electric furnace yielded him metallic niobium and tantalum; many metals of the rare earths; and borides of silicon. A silicide of lithium, Li_6Si_2, was prepared; and a new hydride of silicon, Si_2H_6, the analogue of ethane. He also studied the acetylides of metals of the alkalies. His last research, of which an account appeared in the 'Comptes Rendus' for 1906, p. 675, dealt with the distillation of titanium in the electric furnace. In all, he published more than 300 memoirs and notices.

This incomplete account of Moissan's work shows how productive his laboratory was; he was full of new ideas, most of them offshoots of his original great discoveries; much of his work was carried out in conjunction with students, of whom an increasing number came from abroad; for his reputation both as a skilled chemist and as an attractive personality had become world wide. His work lay almost entirely in the field of inorganic chemistry; and it contributed to turn the tide which had set so long in favour of organic research.

He published, along with many other collaborators, a treatise on inorganic chemistry—"Traité de Chimie Minérale"—in five large volumes, which has already a large circulation in France, and in point of detail is a very complete account of inorganic compounds.

Moissan was the recipient of numerous honours, not only in his own country, but also abroad. In 1888, after his isolation of fluorine, he was elected a member of the Académie de Médecine; in 1891, of the Académie des Sciences; in 1895, membre of the Conseil d'Hygiène de la Seine; and in 1898, of the Comité Consultatif des Arts et Manufactures. He was foreign member of the Royal Society of London; an honorary member of the Royal Institution and of the Academies of Denmark, Vienna, Belgium, Upsala, Haarlem, Amsterdam, New York, and Turin, besides numerous others. He was also Commandeur de la Légion d'Honneur.

In 1887 the Institut awarded him the Prix Lacaze, one of its most valuable gifts; he was the Davy medallist in 1896, and the Hofmann medallist in 1903; and he obtained honours from the Franklin Institute of Philadelphia, from the Société d'Encouragement pour l'Industrie Nationale, and the Société Industrielle du Nord de la France. And in 1906, shortly before his death, he was awarded the Nobel Prize for Chemistry.

Moissan was a practised speaker, and a perfect expositor. His lectures at the Sorbonne were crowded by enthusiastic students, all eager to catch every word; and he kept their attention for an hour and three quarters at a time, by a clear, lucid exposition, copiously illustrated by well-devised experiments. His command of language was admirable: it was French at its best; the charm of his personality and his evident joy in exposition gave keen pleasure to his auditors. He will live long in the memories of all who were privileged to know him, as a man full of human kindness, of tact, and of true love of the subject which he adorned by his life and work. Perhaps the key to his character lies in his own words:—"Nous devons tous placer notre idéal assez haut pour ne pouvoir jamais l'atteindre"; or, as our own poet has put it:—"O but a man's reach should exceed his grasp; or what's a heaven for?"

W. R.

WILLIAM HENRY PERKIN, 1838—1907.

Sir William Henry Perkin, whose death occurred on July 14, 1907, was born in London on March 12, 1838. He was the youngest son of Mr. George Fowler Perkin, a builder and contractor, who died in 1865 at the age of 63. The younger Perkin received his early education at a private school, and was afterwards sent to the City of London School, where it may be said that his inborn talent for chemistry as a science first took definite form through the encouragement of the late Thomas Hall, who was at that time one of the class masters in the school. Science at that period apparently did not form a recognised part of the educational curriculum, since Mr. Hall had to take the time for giving two weekly lectures on chemistry and natural philosophy out of the dinner interval. The schoolboy Perkin attended these lectures with the greatest delight, often sacrificing the midday meal in his enthusiasm, and was soon promoted to the, to him, proud position of being allowed to prepare the experiments, and help Mr. Hall with the demonstrations during the lectures.

It is evident that in the case of Perkin, as is so generally the case with those who leave their mark upon any branch of science, the particular specialisation of faculty and disposition indicative of inherent ability revealed itself at a comparatively early age, and it is certainly a fortunate circumstance that at this critical period of his career he should have fallen under the influence of Mr. Hall, who was himself a pupil of Hofmann's, and who, according to all accounts furnished by contemporaries, must have been highly inspiring as a teacher of science. Perkin has quite recently placed upon record the history of his early life in the following passage:—

"As long as I can remember, the kind of pursuit I should follow during my life was a subject that occupied my thoughts very much. My father being a builder, the first idea was that I should follow in his footsteps, and I used to watch the carpenters at work, and also tried my hand at carpentering myself. Other things I noticed led me to take an interest in mechanics and engineering, and I used to pore over an old book called 'The Artisan,' which referred to these subjects and also described some of the steam engines then in use, and I tried to make an engine myself and got as far as making the patterns for casting, but I was unable to go any farther for want of appliances. I had always been fond of drawing, and sometimes copied plans for my father, whose ambition was that I might be an architect. This led me on to painting, and made me think I should like to be an artist, and I worked away at oil painting for some time. All these subjects I pursued earnestly and not as amusements, and the information I obtained, though very elementary, was of much value to me afterwards. But when I was between twelve and thirteen years of age, a young friend showed me some chemical experiments, and the wonderful power of substances to crystallise in definite forms, and the latter, especially, struck me very much, with the result that I saw there was in chemistry something far beyond the other pursuits with which I had previously been occupied. The possibility also of making new discoveries impressed me very much. My choice was fixed, and I determined if possible to become a chemist, and I immediately commenced to accumulate bottles of chemicals and make experiments."

It was at this period that Perkin entered the City of London School, and, as he has told us in the passage just quoted, with a distinct bias towards chemistry as a career. This decision appears to have caused his father some disappointment, as at that time chemistry as a profession offered but few attractions, and it was only through the intercession of Mr. Hall that he was allowed, at the age of fifteen, to enter the Royal College of Chemistry as a student under Hofmann in the year 1853. His special ability must have revealed itself also to the eminent professor who was at the head of that institution, for he soon passed through the ordinary course of training, consisting of qualitative and quantitative analysis and gas analysis, and, by the end of his second year, had, under Hofmann's guidance, carried out his first piece of research work. In describing this period of his career in a speech delivered in New York in October, 1906, Perkin significantly added with respect to the ordinary curriculum which all students of the Royal College of Chemistry went through at that time:—"This I looked upon only as a preliminary part of my chemical acquirements and not, as many used to and some still do, as a full equipment. Research was my ambition . . ."

For a youth with these proclivities, no more inspiring influence existed in this country than that exercised by Hofmann in the research laboratory in Oxford Street, and at the age of seventeen we find Perkin, who had by then proved his capabilities, enrolled as honorary assistant to the Professor. In that laboratory the first serious insight into research methods was acquired, and it is of particular interest to note that his initiatory work, instigated by Hofmann, was in connection with the hydrocarbon anthracene, a substance which, a few years later, served as the starting point in one of the most brilliant synthetical achievements in scientific and industrial chemistry, with which the name of Perkin will be always associated. No less interesting is the circumstance that this first research, although, for reasons which are now readily intelligible, ending in negative results, in no way daunted the ardour of the young investigator, who, in later life, frequently declared that his first efforts at getting definite products from anthracene were of invaluable service to him when he again took up the study of this hydrocarbon from the scientific and technical point of view. The problem set by Hofmann was, in fact, not solved until more than a quarter of a century after Perkin's first attempt, and then by a very indirect method. The general subject which, among others, was under investigation in the Oxford Street laboratory at that time was the production of organic bases from hydrocarbons by the reduction of the nitro-derivatives. Anthracene, then known as "paranaphthalene," had not been brought within the range of these experiments, and the task of isolating the hydrocarbon from coal-tar pitch with a view to nitrating the pure substance was entrusted to Perkin, whose difficulties in attempting on a laboratory scale to achieve a result which is only satisfactorily accomplished on a factory scale are readily imaginable. However, the aid of the tar distiller was invoked, and a supply of the raw anthracene obtained from the Bethels Tar Works, but the pure hydrocarbon could not be nitrated, and so the desired amine corresponding to aniline could not be obtained. As a matter of fact, Perkin had unwittingly produced, by the action of nitric acid upon anthracene, the parent substance of alizarin, anthraquinone, although his analyses failed to reveal the nature of the compound, because at that time an erroneous formula had been assigned to the hydrocarbon by its discoverers, Dumas and Laurent. Other (haloid) derivatives of anthracene prepared during the research for a similar reason failed to give intelligible results on analysis, and the young investigator was therefore given another piece of work, viz., the study of the action of cyanogen chloride upon naphthylamine, this being a part of a general research upon the action of cyanogen chloride, etc., upon organic bases, which had, for some time, been going on under the auspices of Hofmann. This second investigation was brought to a successful issue and communicated a year later to the Chemical Society of London, which then held its meetings at a house in Cavendish Square.

Perkin's first successful research was thus completed in 1855 and appeared in the Journal of the Chemical Society in 1856 (vol. 9, p. 8; also Liebig's 'Annalen,' vol. 98, p. 238) from which time, throughout the whole period of his career, that Society received and published practically the whole results of his scientific labours.

The compound described by Perkin in his first paper as "menaphthylamine," in accordance with the nomenclature of the period, is the α-dinaphthylguanidine of modern chemistry. But one naphthylamine was known at that time, and the possible existence of a second modification could not, in the existing state of chemical theory, have been foreseen. That the work and the worker found favour in the estimation of Hofmann is shown by the circumstance that on its completion he was promoted from the position of honorary assistant and made a member of the research staff, his colleague being Mr., now Professor, Arthur Herbert Church, with whom Perkin formed a friendship which lasted throughout his life. It was at this period of his career that he made that discovery of the dyestuff mauve, which for a time diverted his attention from pure to applied science, although, as is now well known, the cause of pure science was advanced at a later period by this discovery to an extraordinary degree, and in many directions quite unforeseen at the time. The story of the discovery of the first coal-tar colouring matter has been frequently placed upon record, and the fiftieth anniversary was made the occasion for an international celebration in London, in July, 1906, when Perkin became the central figure and received the homage and congratulations of chemists and technologists from every part of the world. Seldom, if ever, in the history of science has the discovery of one chemical compound of practical utility led to results of such enormous scientific and industrial importance as this accidental preparation of mauve in 1856. The details of the working out of the manufacturing process and of the methods for utilising the dyestuff belong to the history of applied science, but since the discovery was the outcome of purely scientific antecedents, and its achievement a matter which materially affected Perkin's career, it is necessary to recapitulate this chapter of his activity in the present notice.

The remarkable zeal which Hofmann's young assistant must have thrown into his work is well revealed by the circumstance that even the activity of the Oxford Street laboratory failed to satisfy his craving for research. He was at that time kept at work upon the investigations prompted by that illustrious professor whose resourcefulness appeared to be inexhaustible, and had little or no time for working independently. He accordingly fitted up, in 1854, a part of a room as a laboratory in his own home,* and there carried on his researches after the day's work at the College was over and during the vacation. It is of considerable interest to note that even at this early period his work brought him into contact with colouring matters, for, having secured the co-operation of his colleague, Mr. Church, one of the first pieces of work which they took in hand was the investigation of the products of reduction of dinitrobenzene and dinitronaphthalene. From the latter there was obtained a coloured substance which, in accordance with the prevailing views concerning the nature of such compounds, was named "nitrosonaphtyline," and a brief account of it was given to the Royal Society by Hofmann on February 6, 1856,† the complete description being afterwards published in the names of Perkin and Church in the Journal of the Chemical Society.‡ The interest attaching to this colouring matter is that it was the first representative of the large and important group of azo-dyes derived from naphthalene ever manufactured, although its true nature was, of course, at first unknown to its discoverers, and even its ultimate composition was not accurately established at the time, because, seven years later, when Perkin and Church resumed the study of the compound, they found that it contained no oxygen, as had at first been supposed, and that it could be made more conveniently by the action of a nitrite upon a salt of α-naphthylamine in the presence of alkali. The substance was renamed, in accordance with current notions, "azodinaphthyldiamine," and the amended results published by the Chemical Society.§ A patent was also secured (No. 893 of 1863)‖ and the substance had a limited use as a dyestuff. The azodinaphthyldiamine of 1863 is the α-aminoazonaphthalene of modern chemistry, and, it may be added, is of no importance in tinctorial industry at the present time.

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[*] His father's house was at that time known as "King David's Fort," Shadwell, E. The name is still preserved in King David's Lane.

[†] 'Roy. Soc. Proc.,' vol. 8, p. 48.

[‡] 'Quart. Journ.,' 1857, vol. 9, p. 6.

[§] 'Chem. Soc. Journ.,' 1863, vol. 16, p. 207.

[‖] It has been pointed out by Caro ('Berichte,' 1891, vol. 24, Appendix, p. 3) that this patent is the first claiming the production of a sulphonated azo-colour.

The discovery of a compound which happened to be a colouring matter was at this stage of Perkin's career an accidental circumstance, as was, in fact, the discovery of mauve, which was made in this same rough home laboratory about the same time, viz., the Easter vacation of 1856. In view of the widespread notion that discoveries of industrial value are invariably the result of researches directed solely towards this practical end, it may be of interest to place once again upon record the statement that the first coal-tar colouring matter was discovered by Perkin as the outcome of as distinct a piece of pure scientific research as was possible in the light of the theoretical conceptions of that period. It must be borne in mind that in 1856 organic chemists had practically nothing to guide them in expressing the formulæ of compounds but the ultimate composition derived from analytical results. It is true that the possibility of different substances having the same ultimate composition had, since the time of Wöhler and Berzelius, received recognition among chemists, but these early ideas concerning isomerism had not yet given birth to those definite conceptions of chemical structure which at a later period resulted from the application of the doctrine of valency. Thus in 1856 it was scientifically legitimate to set out from the assumption that a natural product might be synthesised if the elements composing it could be brought into combination in the right proportions. Many attempts to produce natural compounds artificially had been made on this principle since the fundamental synthesis of urea from ammonium cyanate by Wöhler in 1828, and although no success in the way of the desired syntheses can be recorded, there can be no doubt that many indirect results of lasting importance to chemical science were arrived at in this way. The discovery of mauve by Perkin is an example of such an indirect result which at first ranked as an industrial success only, and, it may now be said fortunately, for a time diverted the energies of its discoverer from the field of pure science to that of chemical industry.

In so far as the discovery of mauve is attributable to scientific as distinguished from purely technical research, it may be pointed out that in accordance with the prevailing belief that a synthetical product, if of the same empirical formula, would prove to be identical with the natural compound, Hofmann, as far back as 1849 had, as Perkin himself indicates in the Memorial Lecture,* suggested the possibility of synthesising quinine from naphthalene, the ground for this suggestion being that the base "naphthalidine" (= naphthylamine) was at that time supposed to differ from quinine only by the elements of two "equivalents" of water, so that if the hydration of the base could by some means have been effected, quinine might be expected to be the result.† Ideas of this order were prevalent in the chemical world about the middle of the nineteenth century, and Perkin has told us how, imbued with these notions, he was "ambitious enough to wish to work on this subject of the artificial formation of natural compounds."* Following the method then in vogue, he came to the conclusion that the most likely generator of quinine would be allyltoluidine, since two "equivalents" of this compound, by taking up oxygen and losing hydrogen (in the form of water), would give a substance of the formula of quinine—

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* 'Chem. Soc. Trans.,' 1896, vol. 69, p. 603.

† 'Reports of the Royal College of Chemistry,' 1849, Introduction, p. 61.

$$2C_{10}H_{13}N + 3O = C_{20}H_{24}N_2O_2 + H_2O.$$

The experiment was tried, a salt of allyltoluidine being oxidised by potassium dichromate, but, instead of quinine, a "dirty reddish-brown precipitate" was obtained. This result, negative in one sense, still appeared of sufficient interest to the young investigator to be worth following up, and he repeated the experiment with a salt of the simpler base aniline, obtaining in this case a very dark-coloured precipitate, which, on further examination, was found to be a colouring matter possessed of dyeing properties. Thus was discovered the first of the coal-tar dyes, the subsequent and rapid development of which, from a laboratory curiosity into a technical product, brings into strong prominence the extraordinary combination of energy, skill, and resourcefulness inherent in this youth, who at the time was not much over seventeen years of age. The very fact of his continuing the investigation of what the majority of contemporary chemists would have discarded as an unpromising "Schmier," may be taken as an indication of his originality, for it must be remembered that, at that time, the main object of research in organic chemistry was to obtain definite crystalline compounds, and the formation of non-crystalline, and especially of coloured, amorphous products, was considered as an indication of the failure of a reaction. This view of research method was particularly upheld in Hofmann's laboratory, and, as has frequently been pointed out by many critics of the too-rigid enforcement of this method, there can be no doubt that the discovery of the coal-tar dyes was considerably retarded by the liberal use of animal charcoal as a decolourising material. Hofmann himself, for example, is well known to have prepared rosaniline in 1858 incidentally as a by-product in the course of his study of the reaction between carbon tetrachloride and aniline, although, so far as concerned the main objects of his research, he regarded it as an impurity. To Perkin must be given the credit of having the courage to break through the traditional dislike of investigating coloured, resinous-looking products, an achievement which, in the case of mauve, may, perhaps, be attributed to that rare combination of the scientific and artistic faculties which he was known to possess. The fact that his new product on purification gave a compound which, at that time, would be considered as imparting a beautiful shade of colour to fabrics when used as a dye, may fairly be claimed to have appealed to his æsthetic sense, and to have lured him on with his research, independently, at first, of immediate practical developments. Professor A. H. Church, his colleague and co-worker, has supplied the following statement with respect to this period of his career:—

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* Hofmann Memorial Lecture, *loc. cit.*

"It was, I think, in October, 1853, that William Henry Perkin entered the Royal College of Chemistry, and was assigned the next bench to mine in the front of the building, looking out upon the street. One year before this date I had gone through my novitiate, and had been awarded what was called a scholarship—still receiving instruction and attending the lectures, but paying no fees. Indeed, I had been carrying out from time to time some minor researches suggested by Dr. Hofmann. Perkin and I soon found we had several interests in common. We were both given to painting, and were amateur sketchers. I was introduced to his home at King David's Fort, and we began painting a picture together. This must have been soon after the Royal Academy Exhibition of 1854, when I had a picture hung. I was nearly four years Perkin's senior, but was soon impressed by his mental activity and his devotion to work.

"I remember the epoch-making experiment in which mauve was first discovered. He repeated it in my presence for my particular benefit. I distinctly recollect strongly urging him to patent his invention. Shortly after this date I left the college for Oxford, but Perkin and I were in frequent communication, and sometimes worked together after I had taken my degree in 1860, and until my appointment in 1863 to the chair of chemistry at the Royal Agricultural College.

"During the year 1855, and the spring of 1856, Perkin and I were no longer working in the same laboratory, for I had been given a bench in the professor's private laboratory on the ground floor, and was engaged in carrying out some of his most important researches of that period."

The history of the technical development of this discovery has been narrated by Perkin in his Hofmann Memorial Lecture of 1896, and it is only necessary to go through that account in order to realise the magnitude of his achievement. A youth of about eighteen, undaunted by the discouragement of his professor, the greatest living master of organic chemistry, had determined to work out his discovery on a manufacturing scale, with no experience or training as a manufacturer himself, and with no precedent to guide him in the construction of plant for carrying on operations, which had, up to that time, never been conducted on more than a laboratory scale. Hofmann's opposition to his young assistant's leaving the paths of pure science, and embarking upon what, no doubt, appeared to his maturer judgment a most risky undertaking, is quite understandable, and fully justifiable. Everything in connection with the new industry had to be worked out from the very beginning—the methods for the isolation and preparation of the raw materials, as well as the manufacture of the new dyestuff, and the prejudices of the dyers and printers against innovation had also to be overcome. With all this responsibility ahead of him, Perkin, encouraged, no doubt, by the favourable report concerning the dyeing qualities of his new product furnished by certain practical dyers, and especially by Messrs. Pullar, of Perth, formally resigned his position at the Royal College of Chemistry, and boldly entered upon his career as an industrial chemist. He has touchingly placed upon record his indebtedness to his father, who, although, as already stated, at first inclined to be adverse to his taking to chemistry as an occupation, had, at the time of the discovery of mauve, so much confidence in his son's ability that he threw in his lot with the new venture, and devoted the greater part of his life's savings to the building of a factory, for which a site had been secured at Greenford Green, near Sudbury, at which latter place Perkin afterwards resided. His elder brother,* Thomas D. Perkin, who, during the summer vacation of 1856, had assisted in making mauve in the laboratory on a somewhat larger scale, in order to supply specimens for testing by the dyers, also joined in the undertaking. A patent was secured (No. 1984, August 26, 1856), and the building of the works commenced in June, 1857, and six months later the new dyestuff, under the name of "Aniline Purple," or "Tyrian Purple," was being manufactured in sufficient quantity to supply one of the London silk dyers.† The subsequent development of this precursor of the coal-tar dyes forms an interesting and, indeed, a romantic chapter in the history of applied science. Its reputation spread rapidly; from silk dyeing its application was extended to cotton dyeing and to calico printing, and at every stage of a career, which may be fairly described as triumphant, the master hand of William Henry Perkin can be detected. Now we find him working out processes for the manufacture of nitrobenzene and aniline on a scale never before attempted, then we learn of his introducing improvements into the methods of silk dyeing on the large scale, and of his discovering suitable mordants for enabling the dyestuff to be applied to cotton fibre both by dyers and calico printers. Well may it be said in Perkin's own words: "In fact, it was all pioneering work."‡

In spite of these splendid pioneering efforts, however, it seems that the recognition of the value of the product at first took place but slowly in this country, and it was not until it had been taken up in France that its merits for tinctorial purposes became generally recognised. In a private communication addressed to the writer of this notice on April 3rd, 1906, Perkin states:—"The value of the mauve was first realised in France, in 1859. English and Scotch calico printers did not show any interest in it until it appeared in French patterns, although some of them had printed cloth for me with that colour." The "Société Industrielle de Mulhouse," it may be added, awarded him a silver medal for his discovery in 1859, and afterwards a gold medal.§ It is of interest to note also that a paper was read by him at the Leeds Meeting of the British Association, in 1858, under the title:

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* Born 1831, died 1891.

† The name "Mauve," by which it was afterwards generally known, was given to the dyestuff in France.

‡ Speech at the Jubilee Banquet in New York, October 6, 1906. See also the Hofmann Memorial Lecture, *loc. cit.*, p. 609.

§ The impetus given to the new colouring matter through French influence was also referred to by Perkin in his reply to Professor Haller at the Jubilee Meeting in 1906 (Report, p. 11); see also 'Journ. Society of Dyers and Colourists,' April, 1907, p. 106.

"On the Purple Dye obtained from Coal Tar" (Reports, 1858, p. 58), when specimens of the substance and fabrics coloured by it were exhibited. No more appropriate place than this town, in the centre of one of the chief seats of the tinctorial industry in Great Britain, could possibly have been selected for bringing the discovery under the notice of chemists and technologists. Sir John Herschel was President of the Chemical Section, and by a remarkable coincidence, in the opening address of the President of the Association, Professor (afterwards Sir Richard) Owen, there occur the following passages *à propos* of the general progress of organic chemical synthesis:—"To the power which mankind may ultimately exercise through the light of synthesis, who may presume to set limits? . . . . . Already, natural processes can be more economically replaced by artificial ones in the formation of a few organic compounds . . . . . It is impossible to foresee the extent to which chemistry may ultimately, in the production of things needful, supersede the present vital agencies of nature." This pronouncement at the Meeting when the first of the coal-tar colouring matters was exhibited —a discovery which laid the foundations of an industry which now supplies as tar products the colouring matters of madder and indigo—may be looked upon as prophetic.

With the increase in the demand for the new colouring matter, the Greenford Green factory had to be enlarged, and at one period the quantity of mauve required by the dyers and printers was more than could be supplied by the working plant in use. An archil dye of a somewhat similar shade, made in France, was introduced into this country under the name of "French Purple," and used as a substitute for mauve, pending the execution of the orders received at Greenford Green. The scale of manufacture of the raw material had necessarily to be also increased, and it appears that the resources of the Greenford factory were so taxed that the aid of another firm of chemical manufacturers had to be secured in order to prepare nitrobenzene. This firm, Simpson, Maule, and Nicholson, had an establishment at Locksfields, in the south of London, and their connection with the early history of the new industry is of interest, for the reason that at a later period they also took up the manufacture of coal-tar colouring matters, Mr. Edward Chambers Nicholson, who had, about a decade before the discovery of mauve, been among Hofmann's most brilliant pupils, having during his connection with this branch of manufacture made many discoveries of the greatest importance. In calling attention, however, to the rapid growth of the coal-tar colour industry, it may be necessary to insert a caution in order to prevent an exaggerated idea of the scale of operations being formed by those who are unacquainted with the details of the early stages. The production of the raw materials and of the finished product was large only in comparison with the laboratory operations conducted in glass flasks, beakers, and retorts. But even when transferred to the factory, the operations were carried on at first on what would now be considered only an experimental scale with very primitive appliances, so enormously has the size and perfection of the plant in this branch of manufacture been increased since the foundations were laid by Perkin in 1856.*

The influence of this inaugural work by Perkin upon the subsequent history of the industry is too well known to need recapitulation. It is only necessary to point out that the introduction of aniline—at that time a mixture of homologues—into the market soon led other investigators to enter the field of colour chemistry, and new dyestuffs made their appearance in rapid succession, the most noteworthy after mauve being magenta, which was discovered as a technical product in 1859, by Verguin, and manufactured for a short period by his process† by the firm of Renard Frères et Franc, of Lyons. In fact, the stream of competition in the course of a few years turned against the original mauve, the demand for which gradually fell off as other colouring matters of a similar or brighter hue were introduced. The consideration of chief interest in connection with Perkin's successful venture into the domain of applied chemistry is, however, from the present point of view, the influence which his work in this field exerted upon pure science. That it has exerted an enormous influence is now generally recognised, and a critical examination of the course of development of the industry will show that the gain by chemical science has been of a twofold character—a direct and an indirect gain.

In the first place, as the direct result of introducing into commerce in large quantities organic chemical products which had before been but laboratory curiosities, a great stimulus was given to research, and chemical workers of the highest repute took up the investigation of the new products, both raw materials and colouring matters. As an indirect consequence, also, many new compounds of industrial value were discovered incidentally in the course of manufacturing operations conducted on the large scale, and these, with the colouring matters which from time to time appeared as novelties, furnished endless subject matter for research, the results so obtained often proving of the greatest scientific importance. Not the least interesting circumstance in connection with this chapter of chemical history is the fact that Hofmann himself soon entered the field of tinctorial chemistry, to which he made many contributions of the utmost value both from the scientific and technological point of view. He was, in fact, for many years recognised as the leading scientific authority on coal-tar colouring matters, and many of his discoveries were practically utilised in the factories. Then, again, there can be no doubt that the success of the new industry and the succession of important scientific discoveries which followed its development attracted large numbers of students into the chemical schools, and many gifted and active workers were by this means drawn as recruits into the ranks of scientific chemists. It is, indeed, not going too far to say that the discovery of the coal-tar colouring matters brought about such a revival in the study of organic chemistry, and particularly in that of the so-called "aromatic" series, that when the epoch-making conception concerning the constitution of these compounds had been given to the world by Kekulé in 1865, the rapid extension of the "benzene theory" was enormously facilitated by the resources which the new industry had given to pure science. If it is true that the new theory materially advanced the cause of the industry, it is no less true that the industry contributed to the advancement of the theory, the verification of which might have been delayed for a generation or more without such support. No better illustration of the interdependence of science and industry has ever been given to the world than this particular example of the action and reaction between theoretical and applied chemistry.*

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* The manufacture of nitrobenzene was at first carried on in large glass flasks or "boltheads" and it was even impossible in the early days to get nitric acid of sufficient strength to nitrate the benzene, so that a mixture of sulphuric acid and sodium nitrate had to be used. It was afterwards found that cast-iron vessels could be employed, and the scale of production was thus considerably increased. It may be of interest to place upon record that there still survives at an advanced age one of the men, William Underwood, who was employed in the early manufacture of nitrobenzene at the works in Locksfields in 1856, and who remembers the development of the operation from "boltheads" to iron stills. This information has been furnished to the writer by Dr. W. Fleming, of Pirbright, who knows and has attended the man.

† By heating crude aniline (*i.e.*, aniline containing toluidine) with stannic chloride.

The success of the new industry not only reacted upon the science of chemistry in the way indicated, but it may be claimed that, contrary to Hofmann's forebodings, it proved in the long run beneficial in every way to Perkin himself, and through him to that science to which he devoted his life. He has told us that when, being fully convinced of the value of mauve, he announced his intention of leaving the College of Chemistry and taking up the manufacture of the new colouring matter, he determined not to allow the manufacturing career to check his research work, and nobly did he adhere to his resolution. His published papers show that in spite of all his technical work the stream of original investigation was never allowed to stagnate. Only a year after the starting of the Greenford works, viz., in 1858, in conjunction with Duppa, he discovered that aminoacetic acid or "glycocoll," a compound which up to that time had only been prepared by the decomposition of natural products, could be obtained by heating bromoacetic acid with ammonia.† A general survey of his work during his connection with the coal-tar colour industry, which ceased in 1874, brings out very clearly the double line of thought which during that period actuated his research work. Concurrently with the investigation of the dyestuffs, he carried on researches in other departments of organic chemistry which had at that time no relations with tinctorial chemistry. Thus we find that by 1860 he, in conjunction with Duppa, had discovered the relationship between tartaric and fumaric-maleic acid, and had effected the synthesis of racemic acid from dibromosuccinic acid, a line of work which was followed up with signal success.* About 1867 he must have commenced those researches on the action of acetic anhydride upon aromatic aldehydes which led to such important developments and culminated in that beautiful method of synthesising unsaturated acids now known as the "Perkin synthesis." The first paper of this series bore the title "On the Action of Acetic Anhydride upon the Hydrides of Salicyl, Ethylsalicyl, etc.,"† and as the outcome of this work the synthesis of coumarin, the odorous substance contained in Tonka Bean, etc., was announced the following year.‡ The production of a vegetable perfume from a coal-tar product was thus first made possible by Perkin, and the continuation of this work, after his retirement from the industry, led to his celebrated discovery of the synthesis of cinnamic acid from benzoic aldehyde, an achievement which subsequently, in the hands of Adolf v. Baeyer and H. Caro, made possible the first synthesis of indigo from tar products.§ It is of interest to note also that while still in the coal-tar colour industry he took part in the discovery of synthetical methods for producing glyoxylic acid from dibromacetic and bromoglycollic acids, thus giving the first insight into the constitution of glyoxylic acid, a result of considerable significance in view of the important part attributed by many modern chemists to this acid in the photosynthetic processes going on in growing plants.||

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* The consideration of the later important influence upon other branches of science arising, often in most indirect and unforeseen ways, from the applications of coal-tar products to such subjects as bacteriology, histology, therapeutics, photography, etc., would swell this notice to an inordinate extent. Although results of incalculable value have been achieved in these fields, Perkin himself is not particularly identified with any of the lateral developments of his initial pioneering labours. References to this aspect of the subject were made in some detail at the Jubilee celebration in 1906. (See the official Report published by the Memorial Committee, and also a paper by Dr. Hugo Schweitzer in 'Science,' No. 616, October 19, 1906, p. 481.)

† Perkin and Duppa, 'Liebig's Annalen,' vol. 108, p. 112. This discovery is specially referred to, not only as illustrating Perkin's extraordinary activity during this busy period, but also because the compound is the type of a large group of amino-acids which of late years have become of extreme importance owing to their relationship to the proteins, as shown by Emil Fischer and his co-workers.

The research work done during Perkin's colour-making period was carried on in a laboratory in a house just outside the Greenford factory, where also the scientific investigations in connection with the colouring matters were conducted, the double line of work already indicated being revealed by the papers published during that period. It has not been considered necessary to give a complete list of these papers in the present notice, but it will be of

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* Perkin and Duppa, 'Liebig's Annalen,' 1860, vol. 115, p. 105; 'Chem. Soc. Journ.,' 1860, vol. 13, p. 102; Perkin, 'Chem. Soc. Journ.,' 1863, vol. 16, p. 198; Perkin and Duppa, 'Liebig's Annalen,' 1864, vol. 129, p. 373; Perkin, 'Chem. Soc. Proc.,' 1888, vol. 4, p. 75.

† 'Chem. Soc. Journ.,' 1867, vol. 20, p. 586.

‡ "On the Artificial Production of Coumarin and Formation of its Homologues," 'Chem. Soc. Journ.,' 1868, vol. 21, pp. 53 and 181.

§ "A Preliminary Notice of the Formation of Coumarin, Cinnamic Acid, and other similar Acids," 'Chem. News,' 1875, vol. 32, p. 258; "On the Formation of Coumarin and of Cinnamic and of other Analogous Acids from the Aromatic Aldehydes," 'Chem. Soc. Trans.,' 1877, vol. 31, p. 388.

|| Perkin and Duppa, 'Chem. Soc. Journ.,' 1868, vol. 21, p. 197.

interest to call attention to the fact that the purely scientific study of the colouring matters undertaken at this time centred round his early discoveries. It was in this new laboratory at Greenford that he and Church continued the investigation of "azodinaphthyldiamine" already mentioned, and discovered a method for resolving this compound by complete reduction, thus introducing a process which is still the standard one for determining the constitution of azo-compounds, and at the same time leading to the isolation of the first diamine derived from naphthylamine.* Nor did he allow his scientific interest in his first discovered dyestuff to flag, for one paper on mauve from the purely chemical point of view was published during his connection with the industry and another after his retirement in 1874.†

In 1868 it was shown by Graebe and Liebermann that the colouring matter of the madder, alizarin, one of the most ancient of vegetable dyestuffs and a substance of immense value for tinctorial purposes, was a derivative of the coal-tar hydrocarbon anthracene, and not, as had up to that time been believed, a derivative of naphthalene. The synthesis of this compound was effected by Graebe and Liebermann in that year, and patents for its manufacture from anthracene secured in Germany and in Great Britain, this being the first instance of a natural vegetable colouring matter having been produced artificially by a purely chemical method. This discovery had a great influence upon Perkin's career as an industrial chemist, and may, indeed, be considered to have marked a new phase of his activity in this field. There was no living worker in this country at that time besides Perkin who so completely combined in himself all the necessary qualifications for taking advantage of such a discovery. Imbued with the spirit of his early ambition to produce natural compounds synthetically, with more than a decade's experience as a manufacturer, with the resources of a factory at his disposal, and, not least, with special experience of anthracene as the very substance upon which, at Hofmann's instigation, he commenced his career in research work, it can readily be understood that Graebe and Liebermann's results should have appealed to him with special significance. The first patented process of the German discoverers was confessedly too costly to hold out much hope of successful competition with the madder plant, requiring as it did the use of bromine. Perkin at once realised the importance of cheapening the process by dispensing with the use of bromine, and undertook researches with this object. As a result, the following year (1869) witnessed the introduction of two new methods for the manufacture of artificial alizarin. In one of these processes dichloranthracene was the starting point, and in the other the sulphonic acid of anthraquinone, the first being of special value in this country owing to the difficulty of obtaining at that time "fuming" sulphuric acid in large quantities. The second process, which is the one still in use, had quite independently been worked out in Germany by Caro, Graebe, and Liebermann, and patented in England practically simultaneously with Perkin's.* The subsequent industrial development of this brilliant achievement has now become historical; the artificial alizarin has completely displaced the natural colouring matter, and madder growing as an industry has become extinct. It is of interest, as showing the growth of the new industry, to reproduce Perkin's statement in 1876:—

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* 'Chem. Soc. Journ.,' 1865, vol. 18, p. 173.

† "On Mauve or Aniline Purple," 'Roy. Soc. Proc.,' 1863, vol. 12, p. 713 (abstract); 1864, vol. 13, p. 170 (full paper). "On Mauveïne and Allied Colouring Matters," 'Chem. Soc. Trans.,' 1879, vol. 35, p. 717. In 1861 he lectured before the Chemical Society on the new coal-tar colouring matters, on which occasion, he has told us, Faraday was among his auditors and congratulated him at the end of the lecture.

"The quantity of madder grown in all the madder-growing countries of the world, prior to 1868, was estimated to be 70,000 tons per annum, and at the present time the artificial colour is manufactured to an extent equivalent to 50,000 tons, or more than two-thirds of the quantity grown when its cultivation had reached its highest point."†

The development of this branch of the coal-tar industry in the Greenford Green Factory has also been recorded by Perkin:—

"Before the end of the year (1869) we had produced 1 ton of this colouring matter in the form of paste; in 1870, 40 tons; and in 1871, 220 tons, and so on in increasing quantities year by year . . . up to the end of 1870 the Greenford Green Works were the only ones producing artificial alizarin. German manufacturers then began to make it, first in small and then in increasing quantities, but until the end of 1873 there was scarcely any competition with our colouring matter in this country."‡

This brilliant achievement in technology again served to bring out the purely scientific spirit which animated all Perkin's work. The chemical investigation of anthracene derivatives was carried on concurrently with the industrial development of the factory process, and also after his retirement, about a dozen papers on these compounds having been published between 1869 and 1880. The discovery of a practical process for the manufacture of alizarin thus led to the utilisation of another coal-tar hydrocarbon anthracene, which had up to that time been a waste product, and the methods for isolating and purifying this substance had, as in the case of benzene, etc., to be worked out in the factory. All the difficulties inseparable from large-scale operations with new materials were successfully surmounted by Perkin; the increasing demand for artificial alizarin taxed all the resources of the factory, and by 1873, when the necessity for introducing enlarged plant became imperative, advantage was taken of the opportunity for transferring the works to the firm of Brooke, Simpson, and Spiller, the successors to the firm of Simpson, Maule, and Nicholson, which had co-operated with Perkin in the early days of the mauve manufacture.

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* The patents are, Caro, Graebe, and Liebermann, No. 1936, of June 25, 1869, and W. H. Perkin, No. 1948, of June 26, 1869.

† Presidential Address to Section B of the British Association, Glasgow, 1876, 'Reports,' p. 61.

‡ Hofmann Memorial Lecture, 'Chem. Soc. Trans.,' 1896, vol. 69, p. 632.

The present "British Alizarine Company" afterwards took over the works from Brooke, Simpson, and Spiller, and removed the manufacture from Greenford Green to Silvertown, so that the latter factory is the lineal descendant of the original establishment which gave the first coal-tar colouring matter to tinctorial industry.

On completion of the sale of the Greenford Green Works in 1874, Perkin retired after eighteen years' connection with the industry. In view of the enormous development of this branch of manufacture in later times, it is of interest to recall the circumstance already mentioned that the whole output of the original factory, both in number and quantity of products, would appear quite trivial in comparison with that of one of the great German factories now in existence—a fact which only serves to emphasise the extraordinary fertility of the seed originally planted by Perkin, whose labours as a technologist led, as a practical issue, to the acquisition of sufficient means to enable him to withdraw altogether from the industrial side of chemistry at the comparatively early age of 36, while still in the prime of life. By many who have watched the decadence of the coal-tar colour industry in this country, he has been blamed for cutting himself so soon adrift from his own offspring. There is no doubt that the life of the industry here would have been prolonged if he had kept in touch with it, but it must not be forgotten that at the time of his retirement he left things in a very flourishing condition. Other factories had developed into successful establishments, and Great Britain was well to the front in this branch of manufacture. Neither Perkin nor his contemporaries could have foreseen in 1874 that our position would later be so successfully assailed by foreign competitors. To a man with his most moderate personal requirements, and with the ardour of the original investigator unquenched, the means of retirement—modest enough as compared with the fortunes accumulated by modern successful manufacturers—simply meant the opportunity of giving practical effect to that resolution concerning his mission as a research chemist which he had formed as a youth, which he had adhered to throughout his industrial career, and which it was his desire to carry out untrammelled by business distractions throughout the remainder of his working period.* Industry may, and, no doubt, did, lose by his decision, but science gained by thirty years of his activity from the period of his retirement down, practically, to the end of his life.

The contributions to chemical science which proceeded from Perkin's laboratory after 1874 have, to some extent, been referred to. After his connection with the Greenford Green Factory had terminated, he had a new house built at Sudbury, converting the adjacent house in which he had previously resided into a laboratory, and it was here that from 1875 he continued his investigations of those colouring matters with which his manufacturing experience had brought him into contact, such as mauveïne, the anthracene derivatives, etc. In 1881 he first drew attention to a certain physical property of some of the compounds which he had prepared, viz., their magnetic rotary power, which observation diverted his activity into an entirely new channel. On further development in his hands this method became a powerful weapon in dealing with questions of chemical constitutions, and the remainder of his life was more or less devoted to its elaboration. As Perkin's name must always be intimately associated with this chapter of physical chemistry, it will be of interest to place upon record his earliest observation. In a paper entitled "On the Isomeric Acids obtained from Coumarin and the Ethers of Hydride of Salicyl"* he describes the methyl ether of "α-methylorthoxyphenylacrylic acid," which he had first prepared in 1877, and in this paper occurs the statement:—

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* "The great importance of original research has been one of the things I have been advocating from the commencement of my chemical career, in season and out of season."—From a speech by Perkin at the Jubilee Banquet in London, on July 26, 1906.

"A determination of its magnetic rotary power gave for the yellow ray 2·334, water being taken as 1. Test observations were made at the same time with water and carbon bisulphide, and gave results very nearly identical with those obtained by Becquerel."†

It is not difficult to follow, at least conjecturally, the mental process by which Perkin was enabled to foresee that this property might be utilised for investigating the constitution or structure of chemical molecules, a subject which even at that time was beginning to bristle with difficulties and ambiguous results when handled by purely chemical methods. He had for precedent the success which had attended the study of other optical properties of organic compounds, such as ordinary (not induced) rotary power, dispersion, refractivity, etc., and he threw himself seriously into this line of work, armed with the skill of an accomplished experimenter, and with that true instinct as a chemist which enabled him to deal with his materials in such a manner that his results at once commanded complete confidence, in spite of the circumstance that this kind of work was for him a totally new departure. In 1882 he published a preliminary paper on the application of this method, and a complete account in 1884.‡

From that time onwards the Chemical Society received and published constant instalments of his work, the fertility of the method being shown not only by the long list of papers published in his own name, but also by the numerous observations recorded in the papers of other workers, to whose service his apparatus and his observational powers were frequently and ungrudgingly devoted. His achievements in this field are well summarised in a letter from Professor J. W. Brühl, of Heidelberg, himself one of the pioneers in the application of optical methods for the determination of chemical constitution, sent to the writer of this notice for transmission to Perkin on the occasion of the Jubilee celebration in 1906: "Availing yourself of the marvellous discovery of your great countryman, Michael Faraday, you undertook to investigate the relations between the chemical composition of bodies and their magnetic circular polarisation—that is to say, one of the general properties of all matter. Before you began work there was little, almost nothing, known of this subject, certainly nothing of practical use to the chemist. You created a new branch of science, taught us how, from the magnetic rotation, conclusions can be drawn as to the chemical structure of bodies, and showed that the magnetic rotation allows us to draw comprehensive and certain conclusions as to the chemical constitution of substances, just as we may from another general physical property, viz., refraction and dispersion. And by showing that both these physical methods of investigation lead to completely harmonious results, you did essential service to both the branches of study, and also to chemistry, which they are destined to serve."

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* 'Chem. Soc. Trans.,' 1881, vol. 39, p. 409.

† 'Ann. Chim.,' 1877 (5), vol. 12, p. 22. *Loc. cit.*, p. 411.

‡ "On Rotary Polarisation by Chemical Substances under Magnetic Influence," 'Chem. Soc. Trans.,' 1882, vol. 41, p. 330. "On the Magnetic Rotary Polarisation of Compounds in Relation to their Chemical Constitution; with Observations on the Preparation and Relative Densities of the Bodies examined," *ibid.*, 1884, vol. 45, p. 421. This last paper, which occupies 60 pages of the volume, contains a full description of the apparatus and method of observation.

This last statement by Brühl, which relates to one of the most interesting results of the study of magnetic rotation, has reference to a development of Perkin's work, which brought him into association with the late John Hall Gladstone, the pioneer and leading authority in this country at that time on the relations between refractive and dispersive power and chemical constitution. The correspondence between the results arrived at by these two optical methods forms the subject of a joint paper by Gladstone and Perkin published in 1889.* Eighteen years later, Perkin's last paper, to which attaches the melancholy interest that it was read before the Chemical Society on April 18, 1907, only a few months before his death, bears the title: "The Magnetic Rotation of Hexatriene, $CH_2:CH.CH:CH.CH:CH_2$, and its Relationship to Benzene and other Aromatic Compounds: also its Refractive Power."†

Although, as already stated, the latter part of Perkin's life was devoted mainly to his work on magnetic rotation, he published also during this period a few papers relating to other subjects, among which perhaps the most notable is his contribution to the subject of low temperature combustion, entitled "Some Observations on the Luminous Incomplete Combustion of

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* "On the Correspondence between the Magnetic Rotation and the Refraction and Dispersion of Light by Compounds containing Nitrogen," 'Chem. Soc. Trans.,' 1889, vol. 55, p. 750. The correspondence between Perkin and Gladstone during this period has been placed at the disposal of the writer by Miss Gladstone. The letters are interesting as showing the extreme conscientiousness in every detail with which Perkin carried out his work. The results are embodied in the above paper, and a further contribution by Perkin was published two years later, under the title, "The Refractive Power of certain Organic Compounds at different Temperatures," 'Chem. Soc. Proc.,' 1891, vol. 7, p. 115. In his later papers he dealt with refractivity as well as magnetic rotation ('Chem. Soc. Trans.,' 1896, vol. 69, p. 1; *ibid.*, 1900, vol. 77, p. 267, etc.).

† 'Chem. Soc. Trans.,' 1907, vol. 91, p. 806.

Ether and other Organic Bodies."* The writer of this notice well remembers the keen interest with which the experiments were followed in the darkened meeting room of the Chemical Society at Burlington House when this paper was read. In view of the modern revival in the scientific study of the chemical mechanism of combustion, it is of importance that Perkin's observations should not be allowed to fall into oblivion.

It has been claimed in a previous part of this notice that Perkin's entry into the domain of chemical industry was no real loss, but actually a gain to pure science. His published papers, considered in detail, show that his contributions to "colour chemistry" are far outweighed by his work in other fields. In fact, the extension and completion of the investigation of the dyestuffs of his industrial period is due to other workers, and Perkin's achievements in this direction are, on the whole, more of a technological than of an abstract scientific character, the constitution of most of the colouring matters having been subsequently worked out chiefly by the group of brilliant continental investigators attracted by the success of the new industry, and stimulated by the rapid development in chemical theory then going on in Germany.† But although Perkin has over-shadowed his own achievements as a "colour chemist" by his subsequent career, the whole success of his life, and the inestimable gain which chemical science has derived from his labours, must be directly attributed to his industrial undertakings, for it may safely be asserted that had he not been rendered independent by the success of the Greenford Green Factory, he would never have found an opportunity for that continuous devotion to research which is so essential for the achievement of results of lasting value. Having determined in early life to adopt chemistry as a career, he would of necessity have been compelled to become either a manufacturer or to have entered an educational establishment. In the former capacity he would, no doubt, have succeeded, but in any subordinate post he might have spent long years before acquiring independence. As a teacher his prospects of making a position at the time of his connection with the Royal College of Chemistry were most slender. There were but very few posts which he could have filled; originality as an investigator was of minor importance as a qualification for the teaching profession, and the stamp of university training was generally considered absolutely essential for holding any important appointment in that profession. Perkin in any minor teaching post would have been lost to science. Happily the comparatively rapid financial success of his early discoveries placed him in that category which comprises such names as Cavendish, Herschel, Joule, Murchison, Spottiswoode, Lyell, and Darwin—representatives of that band of independent devotees of science who have more than any other class helped to maintain the prestige of this country. Truly may it be said that to a man of his temperament success as a manufacturer meant salvation as an original worker.

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* 'Chem. Soc. Trans.,' 1882, vol. 41, p. 363.

† For example, the constitution of mauveïne was established broadly by O. Fischer and Hepp about 1880; that of the colouring matters of the rosaniline group (magenta, methyl violet, etc.), by E. and O. Fischer, about 1878, and that of safranine about 1883 by Nietzki.

Reviewing Perkin's scientific work as a whole, its chief characteristic is its solidity. His mind was not of that order which readily entered into the region of speculation; he was a typical representative of that school of chemists to whom the conscientious accuracy of experimental facts is of primary importance—the school which has laid those solid foundations of chemical science upon which all superstructures of theory must be erected. It is for this reason that it may be predicted with certainty that his work will live in the history of modern chemistry whatever changes in theoretical conceptions the future may have in store. He himself witnessed with the progress of the science radical changes in the views of chemists concerning the mechanism of the reactions or the nature of the compounds which he had discovered. With true philosophic spirit he accepted the evidence of other workers and welcomed the legitimate development of his own discoveries. Whatever modification of theory may have been rendered necessary by the accumulated labours of the great and ever-growing army of investigators which he lived to see following the tracks which he had been the first to tread, it may safely be asserted that his own early footprints have been, and always will be, ineffaceable.

Perkin was by disposition a man of extreme modesty and of a most retiring nature. His devotion to science and the domesticity of his character accounted so completely for his time that, beyond participating in the administrative work of the scientific societies with which he was connected, he took but little part in extraneous affairs. He was not particularly of a business turn of mind in the commercial sense, and during his industrial career his brother Thomas was the chief man of business connected with the factory. One line of work distinct from his purely scientific occupations is, however, worthy of special record, because it enabled him to exert some influence in the cause of technical and scientific education. His family had for a long period been connected with the Leathersellers' Company, and through this connection he was enabled to promote the cause of chemical research and also to become, as the representative of his Company, a member of the governing body of the City and Guilds of London Institute, whose meetings he attended with considerable regularity, although, unless specially appealed to, he seldom took part in the discussions at the Council table. But his influence in the City of London, although unobtrusive, was of a most beneficial character, and every movement for the promotion of science and of scientific education was certain to receive his support. His special knowledge of the requirements of the chemical technologist and his sympathy with the teaching staffs have contributed in no small degree to promote the cause of sound chemical education in London through the City and Guilds Institute. As an illustration of the modesty of his character, it may be of interest to relate that many of his colleagues in the City were unaware, until the Jubilee of 1906, that the William Perkin who sat at their meetings was the same man who, half a century before, had laid the foundations of a great industry. The following details concerning his connection with the Leathersellers have been supplied by the late Mr. W. Arnold Hepburn, the Clerk to the Company:—

> "William Henry Perkin, son of George Fowler Perkin, was made free by patrimony, November 13, 1861.
>
> "George Fowler Perkin, son of Thomas Perkin, was made free by patrimony, February 4, 1829.
>
> "Thomas Perkin, apprenticed to Isaac Roberts, March 16, 1772, was made free by servitude, July 7, 1790.
>
> "William Henry Perkin served the office of Steward, 1881–2; 4th Warden, 1885–6; 2nd Warden, 1895–6; Master, 1896–7.
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> "During the Mastership of Dr. Perkin in 1896 the Company, at his instance, resolved to found a Research Fellowship in Chemistry as applied to Manufactures, tenable at the Central Technical College of the City and Guilds Institute, and to grant £150 a year in support thereof."

A portrait of Perkin in his robe as LL.D. of the University of St. Andrews, painted by Henry Grant in 1898, is on the wall at the Leathersellers' Hall in St. Helen's Place.

Although his single-minded devotion to his researches and his retiring nature caused Perkin to remain in comparative obscurity from the point of view of the general public, his real worth was well known to, and received frequent recognition from, his scientific colleagues. In this respect his history is that of the majority of active workers in the field of science in this country who do not wield the pen as *littérateurs*, or whose achievements are not of a sufficiently startling kind to create public notoriety. With the passing of the generation which witnessed the interest aroused by the discovery of mauve, and which was fanned into temporary excitement by the sensational accounts circulated by the newspapers of the period, the memory of Perkin faded from the public mind. To most of his fellow countrymen the memorable international gathering in London in 1906 came as a revelation that they could claim as their compatriot the man whom all the nations had sent their representatives to honour as an individual, and in celebration of the fiftieth anniversary of the discovery of the first of the synthetic dyestuffs.

Perkin was elected into the Royal Society in 1866; he served on the Council in 1879–81, and again in 1892–94. In 1893–94 he was made one of the Vice-Presidents. He joined the Chemical Society in 1856, served on the Council in 1861–62, and in 1868–69; was Secretary from 1869 to 1883, and President from 1883 to 1885. By way of Academic distinctions he received the degree of Ph.D. from the University of Würzburg in 1882; the degree of LL.D. from the University of St. Andrews in 1891; and was made a D.Sc. of Victoria University in 1904. In connection with the Jubilee of 1906, the University of Heidelberg conferred upon him the degree of Ph.D., the Munich Technical High School awarded him the diploma of Dr. Ing., and the same year the Universities of Oxford and Leeds gave him the degree of D.Sc. During his subsequent visit to America in the autumn of 1906, in connection with the celebrations organised in that country, he received the degree of D.Sc. from Columbia University, and LL.D from the Johns Hopkins University, of Baltimore, the latter degree having been most appropriately conferred by his chemical colleague, President Ira Remsen.

He was President of the Society of Chemical Industry in 1884–85, at the time of his death was President of the Society of Dyers and Colourists,* and had recently accepted office as President of the Faraday Society. In 1884 he was made an Honorary Foreign Member of the German Chemical Society. Following the early recognition of his technological work by the "Société Industrielle de Mulhouse," already referred to, he received from the Royal Society a Royal Medal in 1879, and the Davy Medal in 1889; from the Chemical Society the Longstaff Medal in 1888; from the Society of Arts the Albert Medal in 1890; from the Institution of Gas Engineers the Birmingham Medal in 1892, and the Gold Medal of the Society of Chemical Industry in 1898. At the Jubilee Celebration in 1906, Professor Emil Fischer, on behalf of the German Chemical Society, presented him with the Hofmann Medal, and Professor Haller, on behalf of the Chemical Society of Paris, with the Lavoisier Medal.

The influence which Perkin has exerted upon this generation is not to be measured solely by his achievements in pure and applied chemistry. His life was noble in its simplicity and his single-minded devotion to his work, combined with a character known to be religious in the highest and best sense of the term, will bequeath to posterity an enduring example of humility in the face of success which would have marred many men of smaller moral calibre. The financial success of his early manufacturing experience was turned to account simply as a means of advancing science, and no distinction which he ever gained throughout a career which culminated in 1906, when the King conferred upon him the honour of Knighthood, and when the nations of the world assembled to render him homage, had the slightest influence upon the modesty and gentleness of his disposition. It was his personality that caused him to be revered in his domestic circle, and to be beloved by all who enjoyed the privilege of his friendship. Two of the addresses presented at the jubilee meeting in

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* In honour of the founder of the industry this Society has established a Perkin Medal "for inventions of striking scientific or industrial merit, applicable to, or connected with, the tinctorial industries." Perkin's last official act in connection with this Society was to accompany a deputation to the Dyers' Company asking the latter to contribute towards the foundation of a prize for the encouragement of research in tinctorial chemistry. The American Memorial Committee also founded a Perkin medal for American chemists in 1906 in connection with their Jubilee Celebration in New York.

1906 give striking expression to the universal esteem in which he was held as a man :—

"But however highly your technical achievements be rated, those who have been intimately associated with you must feel that the example which you have set by your rectitude, as well as by your modesty and sincerity of purpose, is of chiefest value." (From the address presented by the Chemical Society.)

"You have given to science the allegiance of a noble life, and you have not allowed the seductions of wealth to abate the loyalty of your devotion to truth and knowledge. This is an example for which the age owes you unstinted thanks. . . . Amid these varied activities it is pleasant to know that you have cultivated the full humanity of life. Music and art have found in you a devoted disciple, and in the family and social relationship of life you have shown that science gives a truer interpretation of, and a deeper meaning to, all that is sacred and good in the heart of man." (From the address presented by the Society of Dyers and Colourists.)

Perkin was twice married, his first wife being a daughter of the late Mr. John Lisset; some years after her death he married the daughter of Mr. Herman Mollwo. Lady Perkin, three sons, all of whom have made their mark as chemists, and four daughters survive. Two of his sons, William Henry and Arthur George, were elected into the Royal Society in 1890 and 1906 respectively, and it was always a source of great satisfaction to him to know that all his sons were following in his footsteps. In his general mode of life Perkin was a man of extreme frugality, robust and active to the last. To one of his retiring habits the strain accompanying the jubilee celebrations in 1906 and the subsequent ordeal of his American tour must have been considerable, but he bore all the excitement and fatigue without the least indication of discomfort. Literally he died in harness; a few months previously he had read his last paper before the Chemical Society, and he was looking forward to being able to resume his research work quietly and uninterruptedly after the distractions of 1906. The illness which brought his noble and useful life to an end, which, in view of his activity, cannot but be regarded as premature, did not at first reveal any serious symptoms. The writer of this notice was with him a few hours before his death, and although he complained of suffering pain he spoke hopefully of his condition and anticipated being soon able to leave his room. The illness proved, however, to be more serious than he or his family were aware of; a sudden change for the worse occurred, and on July 14, 1907, he passed away in perfect peace and in the full tide of well-won honour.

R. M.

H. C. RUSSELL, 1836—1907.

Henry Chamberlaine Russell, a son of the Honourable Bourne Russell, was born in 1836 at West Maitland, New South Wales. He was educated at the West Maitland Grammar School, and graduated at the Sydney University in 1858, obtaining the Deas-Thomson scholarship for physics and chemistry. On leaving the university he became assistant at the Sydney Observatory, and in 1870 was appointed Government Astronomer, a post he occupied till his retirement in 1905.

Astronomy in Australia began with the foundation of the Paramatta Observatory by Sir Thomas Brisbane in 1822. Valuable work was carried out by Dunlop and Rumker, but the observatory only continued in operation for a short time, and was dismantled in 1847. For ten years Australia had no observatory, but shortly after the arrival of Sir W. T. Dennison as Governor-General of New South Wales, £7000 was set apart for the building of an astronomical observatory in the colony. On the advice of Sir George Airy, Mr. W. Scott, Fellow and Mathematical Lecturer of Sidney Sussex College, Cambridge, was appointed Government Astronomer. After spending a few months at Greenwich, Mr. Scott arrived at Sydney on November 1, 1856. He chose the best site available for the observatory, on one of the many headlands projecting into Sydney Harbour, and erected a good stone building containing a transit room, an 18-foot dome, and a tower high enough for the time-ball to be visible from the greater part of the harbour and the city. The transit instrument was an old one which had been in use at Paramatta, but a good equatorial, with a 7¼-inch object-glass by Merz, was obtained in 1860. Mr. Scott resigned in 1862, and, after a few months, during which Mr. Russell was Acting Director of the observatory, was succeeded by Mr. Smalley, who was Government Astronomer till his death in 1870.

Immediately on his appointment, in 1870, Mr. Russell commenced to reorganise the instrumental equipment of the observatory. He was well fitted for this task by his mechanical skill and inventiveness, qualities of special value in a country where the fine mechanical work required in the manufacture of scientific instruments was then practically unknown. The observatory buildings were enlarged, a new reversible transit circle, with an object-glass of 6½ inches, was obtained, and, in 1874, a large equatorial, with an object-glass of 11½ inches. The mounting of this instrument, the driving clock, and the dome containing it were made from Mr. Russell's designs. With this instrument a large number of valuable observations of double stars, clusters, and nebulæ have been continuously made by Mr. Russell and his assistants.

Preparations for observation of the transit of Venus in 1874 were begun by Mr. Russell in 1870, as the favourable position of the eastern coast of Australia for observation of egress made it desirable that as extensive a programme as practicable should be carried out. In 1872 the Government of New South Wales voted £1000 for the purpose, and with this sum Mr. Russell proceeded to equip four observing stations. Owing to the short time available, many of the instruments were made in the colony, the more delicate parts under the direct supervision of Mr. Russell. The observations were, generally speaking, very successful, and an interesting account of them was published by Mr. Russell in 1892.

The application of photography to astronomy attracted Mr. Russell; in 1887 he attended the Astrographic Congress at Paris, and promised the co-operation of the Sydney Observatory. In the same year the purchase of a photographic objective of 13 inches aperture was sanctioned; but as the mounting could be made in Sydney with needful accuracy, it was arranged that this should be made in the colony. The equatorial mounting, the driving clock, and various accessories of the instrument were accordingly made from Mr. Russell's designs. The mounting was finished in 1890, before the object-glass arrived from Europe, and the interval was employed in taking photographs of nebulæ and other interesting objects of the southern skies with a Dallmeyer portrait lens of 6 inches aperture and 32 inches focus. It was found that in the neighbourhood of the city there was sufficient diffused light to produce fogging when long exposures were given. Accordingly, at Mr. Russell's instance, seven acres of land near the Pennant Hills were obtained from the Government, and the instrument and necessary buildings were erected there.

The portion of the Astrographic Catalogue undertaken by the Sydney Observatory extends from 54° to 62° of S. declination. This work, involving the taking and measurement of 1400 photographic plates and the observation of the reference stars at the meridian instrument, was actively carried on under Mr. Russell's direction till the time of his retirement. In connection with this work, he devised an electric control for the driving clock of the equatorial and designed a machine for the measurement of the photographic plates.

Mr. Russell was interested in meteorology no less than in astronomy. At the time of his appointment, in 1870, there were in New South Wales less than a dozen stations where meteorological observations were made. At the time of his retirement he had increased the number to 1800. The returns from these stations were compiled and analysed at the observatory, and published annually under the title, "Results of Rain, River, and Evaporation Observations made in New South Wales." In conjunction with his colleagues at Melbourne and Adelaide, telegraphic exchanges of weather reports were organised, and these were utilised by him for the issue of daily weather forecasts. These predictions, which have been issued since 1887, are stated to be correct in from 80 to 84 per cent. of times, and are of special value in the wheat-producing districts and other country centres.

In 1877 Mr. Russell published an exhaustive treatise on the climate of New South Wales. The historical part of this work presented great difficulties, "the facts being buried under a thousand times their bulk of other matter." From all sources available, including authorities living at the time, he endeavoured to ascertain meteorological data in any particular year or period in the history of the colony. In this way he produced a work of reference on the droughts, floods, and climatic conditions of New South Wales from the times of the first settlers.

In these researches Mr. Russell was animated by the desire to discover in meteorological data some period which would connect them with cosmical phenomena. He wrote several papers on Weather Periodicity and considered he had found evidence for a cycle of 19 years. Whatever views be taken of this, it cannot be denied that his papers contain much valuable systematised meteorological information.

In 1879 Mr. Russell communicated to the Royal Society of New South Wales a short paper entitled "The River Darling: the water which should pass through it." He predicted the occurrence of an unlimited supply of good water in the Darling district, to be derived from the vast supplies of rain water which must sink into the ground to flow at some lower level. This prediction of Mr. Russell's, made at a time when nothing was known of the existence of artesian water in the western plains of New South Wales, was made in reliance on his carefully compiled meteorological data. His colleague in the University of Sydney, Professor David, cites this as an example of the scientific imagination with which Mr. Russell was gifted, leading him to picture results which followed from the phenomena he was considering.

Mr. Russell found in meteorology, no less than in astronomy, scope for his inventiveness. The electric barograph, the recording anemometer and pluviometer of the observatory were designed and largely made by him. They are still in work after 30 years of use.

In 1888 Mr. Russell printed and distributed papers to captains of vessels, with instructions that after the date, latitude, and longitude had been inserted, they should be sealed in bottles and allowed to drift. A number were sooner or later picked up and forwarded to Mr. Russell. From the data thus secured he deduced results as to the velocity and direction of the currents in the Southern Ocean and particularly round the Australian coast. These he communicated to the Royal Society of New South Wales in a series of short "Current Papers." To the same Society he contributed two important papers on Icebergs in the Southern Ocean. The measurement of tides was also taken up by Mr. Russell, and the self-recording tide gauge of Sydney Harbour was made from his design in 1873.

Although Mr. Russell's scientific interests ranged over the wide fields of astronomy, meteorology, and physical geography, he, nevertheless, took an active part in educational questions, particularly in the organisation of technical education in New South Wales. At the time of his death he was the oldest Fellow of the Senate of the University of Sydney and had been Vice-Chancellor in the year 1891. He was four times President of the Royal

Society of New South Wales and was the first President of the Australasian Association for the Advancement of Science. He was elected a Fellow of the Royal Society in 1886. In 1890 he was created Companion of the Order of St. Michael and St. George.

Mr. Russell had a severe illness in 1903, from the effects of which he never entirely recovered. He died on February 22, 1907, and leaves a widow, four daughters and one son.

F. W. D.